PONTIFÍCIA UNIVERSIDADE CATÓLICA
DO RIO DE JANEIRO

Liliana Dennis Mejia Sanchez

Determinants for the success in Public Infrastructure Concessions: an analysis of the importance, impact, and value of the flexibilities included in the concession contracts, using the Real Options approach

Tese de Doutorado

Thesis presented to the Programa de Pós-graduação em Administração de Empresas of PUC-Rio in partial fulfillment of the requirements for the degree of Doutor em Administração de Empresas.

Advisor: Carlos de Lamare Bastian Pinto
Co-advisor: Luiz Eduardo Teixeira Brandão

Rio de Janeiro
April 2024

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To God.
To my family, for always being by my side
and supporting me in the most difficult moments.

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Abstract

Mejia Sanchez, Liliana Dennis; Pinto, Carlos de Lamare Bastian (Advisor). **Determinants for the success in Public Infrastructure Concessions: an analysis of the importance, impact, and value of the flexibilities included in the concession contracts, using the Real Options Approach**. Rio de Janeiro, 2024. 134p. Tese de Doutorado - Departamento de Administração, Pontifícia Universidade Católica do Rio de Janeiro.

This thesis studies concessions and Public-Private Partnerships (PPPs) carried out in Brazil. To analyze the problems, risks, uncertainties, and factors that affect infrastructure projects and proposes a strategy to solve one of the main risks that affect projects: demand risk. In the first part, a systematic literature review on public infrastructure projects and the application of evaluation approaches that incorporate flexibility is carried out. This is the case with the Real Options Approach. This review focuses on the main advances made in the area, current trends, ways to incorporate flexibility, and its evaluation. The second part analyses the main characteristics of concession contracts in Brazil and the factors that generated problems in concessions. This analysis identifies the main problems, similarities, and differences between sectors and displays the strategies used for facing the difficulties. The third part shows trends regarding PPPs in Latin America and the Caribbean. It also highlights a concession model used in ports. Unlike other models, construction is carried out according to demand through triggers. Once the trigger is activated, the investment becomes mandatory. Therefore, it is known as a mandatory option. Finally, a new model is developed in the fourth part to mitigate demand risk and not generate contingent liabilities for the granting authority. This new strategy is called the MRG/GL mechanism, as it combines the Minimum Revenue Guarantee (MRG) with the Accounts Mechanism. The results show that it is possible to reduce demand risk, make projects attractive, and simultaneously reduce the possibility of budgetary burden for the government.

Keywords

Infrastructure projects; Brazil; Minimum Revenue Guarantee; Account Mechanism; Real options.

Resumo

Mejia Sanchez, Liliana Dennis; Pinto, Carlos de Lamare Bastian. **Determinantes do sucesso das Concessões de Infraestrutura Pública: uma análise da importância, o impacto e o valor das flexibilidades incluídas nos contratos usando a abordagem de Opções Reais.** Rio de Janeiro, 2024. 134p. Tese de Doutorado - Departamento de Administração, Pontifícia Universidade Católica do Rio de Janeiro.

Esta tese estuda as Concessões e Parcerias Público-Privadas (PPPs) realizadas no Brasil. Para analisar os problemas, riscos, incertezas e fatores que afetam os projetos de infraestrutura e propõe uma estratégia para resolver um dos principais riscos que afetam os projetos: risco de demanda. Na primeira parte é realizada uma revisão sistemática da literatura acadêmica sobre projetos de infraestrutura pública e a aplicação de abordagens de avaliação que incorporam flexibilidade, como a Abordagem de Opções Reais. Esta revisão centra-se nos principais avanços alcançados na área, tendências atuais, formas de incorporar flexibilidade e sua avaliação. A segunda parte analisa as principais características dos contratos de concessão no Brasil e os fatores que geraram problemas nas concessões. Esta análise identifica os principais problemas, semelhanças e diferenças entre os setores e exibe as estratégias utilizadas para enfrentar as dificuldades. A terceira parte mostra as tendências em relação às PPPs na América Latina e no Caribe. Destaca também um modelo de concessão utilizado nos Portos. Diferentemente de outros modelos, a construção é realizada de acordo com a demanda por meio de gatilhos. Uma vez acionado o gatilho, o investimento passa a ser obrigatório. Portanto, é conhecido como uma opção obrigatória. Por fim, na quarta parte é desenvolvido um modelo para mitigar o risco de demanda e não gerar passivos contingentes para o poder concedente. Esta estratégia é denominada mecanismo MRG/GL, pois combina a Garantia de Receita Mínima (MRG) com o Mecanismo de Contas. Os resultados mostram que é possível reduzir o risco de demanda, tornar os projetos atrativos e, simultaneamente, reduzir a possibilidade de carga orçamental e passivos para o governo.

Palavras-chave

Projetos de infraestrutura; Brasil; Garantia de Receita Mínima; Mecanismo de Conta; Opções reais.

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Acronyms and abbreviations

PPPs - Public Private Partnerships

LAC - Latin America and the Caribbean

ANTT - Agência Nacional de Transportes Terrestres

ANAC - Agência Nacional de Aviação Civil

DCF - Discounted Cash Flow

NPV - Net Present Value

ROA - Real Options Approach

GBM - Geometric Brownian Motion

MRP - Mean Reversion Process

PDE - Partial Differential Equations

MCS - Monte Carlo Simulation

MRG - Minimum Revenue Guarantee

MDG - Minimum Demand Guarantee

MRL - Maximum Revenue Limit

MEL - Maximum Expense Limit

TRC - Toll Revenue Cap

MRC - Maximum Revenue Cap

IRR - Internal Rate of Return

BSM - Black-Scholes-Merton

O&M - Operation and Maintenance

MTG - Minimum Traffic Guarantee

MT - Mato Grosso

EA - Escrow Account

MRG/GL - Minimum Revenue Guarantee with Guaranteed Liabilities

CAGR - Compound Annual Growth Rate

EBITDA - Earnings before interest, taxes, depreciation and amortization

OPEX - Operational expenditures

CAPEX - Capital Expenditure

WACC - Weighted Average Capital Cost.

1
Introduction

Infrastructure development is the backbone of economic growth for any country or region. Infrastructure involves different types of facilities, services, goods, and assets needed to drive the economy. For example, transport systems (airports, ports, highways, roads, rail systems, bridges, and other types of land, air, and sea transport networks); water systems (sewage, wastewater treatment, and water supply); medical facilities (hospitals, health clinics); energy, telecommunications, and others.

Infrastructures, in addition to facilitating the functioning of other systems, also constitute the set of vital inputs for the essential services that companies need to produce and that society requires to live (Cavallo and Powell, 2019), (Grimsey and Lewis, 2002). Thus, the importance of developing physical infrastructure is highlighted.

Unlike other traditional investments, public infrastructure investment focuses on essential projects for society and public welfare (Brandão and Saraiva, 2007). Those responsible for public infrastructure development can be either the Federal or the State Governments. The Federal government focuses on developing infrastructure of national importance and the State governments focus on infrastructure at the local level.

Investment in public infrastructure differs from other types of investment in projects because it requires significantly high capital, they are long-term projects and, therefore, with a long period of economic recovery, they are irreversible and dynamic due to the various uncertainties that can affect them. (Krüger, 2012), and often have monopoly characteristics (Martins et al., 2014).

Due to these characteristics, the public sector often lacks the resources and financial, technical, and operational capacity to carry out them. As a result, many countries cannot develop infrastructure directly. To meet its needs, the granting power (mainly represented by the government or state entities) invites the private sector (companies and other private entities) to participate and invest in infrastructure projects through Public Private Partnerships (PPPs) agreements.

In PPPs, the basic idea is that infrastructure is built using combinations of public and private financing. In which each of the parties has their motivations. The value that the infrastructure has for the private sector is to maximize its financial profitability (Smit, 2003) and the value for society includes socioeconomic benefit (Chiara et al., 2007). According to Brandão and Saraiva (2007), the main benefits of PPPs are increased efficiency by replacing administration (public to private), solving budget problems and restrictions, reducing the tax burden, accessing investment capital and risk distribution.

Unfortunately, evidence shows that infrastructure projects and their implementation are subject to risks and uncertainties. There are several types of risks: technical, pre-construction and construction, operational, demand, financial and revenue, regulatory and political, environmental, and force majeure (Grimsey and Lewis, 2002), (Brandão and Saraiva, 2007). Some other risks also come from the complexity of the agreement itself in terms of documentation and other technical details. These risks can arise at different stages of the project lifecycle (Zhang, 2005). Likewise, the nature of risks can change over the years (Grimsey and Lewis, 2002). Depending on the characteristics of the project, some risks may be more important (with greater impacts) than others (Brandão and Saraiva, 2007). Furthermore, each party in a PPP agreement has its own set of expectations regarding risk allocating and mitigating.

In the past, concession contracts were standardized and rigid. As a result, the private sector was often reluctant to accept the risks and participate in the deals. The very nature of infrastructure projects showed that rigidity and standardization did not encourage private sector participation. To encourage private participation and guarantee investment more flexible contracts were suggested.

These flexibilities can be represented in the form of government support or possibilities to expand, postpone, or abandon the investment. On the one hand, government support aims to attract long-term private participation (Cheah and Liu, 2006). On the other hand, they can also represent liabilities for the government. Especially, if are granted indiscriminately (Brandão and Saraiva, 2008). Furthermore, there is no evidence that the private sector increases its effectiveness when it benefits from many subsidies, guarantees, and supports. For this reason, a balance must be achieved, that is not excessively beneficial to the private sector and does not harm the public sector (Carbonara et al., 2014).

PPPs have been widely used by Latin America and the Caribbean (LAC) countries as a mechanism to develop infrastructure. Compared to other regions of the world, LAC has the highest number of PPPs. The use of this mechanism has intensified mainly in the last ten years, with aggregate investments of approximately US$ 344 billion and 1,074 projects (Reyes Tagel, 2021).

Since the 1990s, there has been a significant increase in infrastructure concessions in Brazil, becoming the best way to meet infrastructure demand in the country. According to Agência Nacional de Transportes Terrestres (ANTT), in total there are approximately 13 thousand kilometers of federal highways under concession. The objective of the Brazilian federal highway concessions is the operation, maintenance, conservation, monitoring, improvements, and capacity expansion of the Highway System (ANTT, 2022). The Agência Nacional de Aviação Civil (ANAC) has already carried out seven rounds of airports.

Brazilian governmental bodies foresee the granting of more infrastructures of different types (roads, airports, ports, and others). However, in recent years several concessions have had problems, such as the Rio de Janeiro Airport, the Natal Airport, and highways: BR-040/DF/GO/MG, BR-163/MS, and BR-060-153-262/DF/GO/MG. In addition to the failed concessions, the vast majority of concessionaires requested revision of the economic-financial rebalancing of signed contracts.

Although revision requests are normal and even adequate for the correct functioning of a concession, the excessive increase in this type of request is a warning that something is not right.

1.1. Research Questions

Reality shows that several factors and risks affect the development of public infrastructure projects. The risks strongly affect the financial stability and continuity of the concession. When there are problems, the government is often conditioned to renegotiate contracts to ensure the continuity of service provision. Thus, it is possible to identify some disharmonies that can lead to the failure of concessions and, therefore, require attention and solutions.

First, concessions and PPPs involve the participation of private investors. Private investors only participate in concessions whenever the value of the project is profitable for them. However, the projects are subject to several risks that can discourage private interest. This shows that mechanisms capable of reducing risks and increasing attractiveness for the private sector are needed, but without generating costs for the government.

Second, for the government the concession of an infrastructure project has several purposes, the main purposes are: i) to develop infrastructure, for which the government does not have the capacity; ii) to supply the demand for missing infrastructure. Besides that, if possible, earn money to invest in other activities. Nevertheless, it is necessary to ponder and order priorities.

Third, Discounted Cash Flow (DCF) is the method currently used to value infrastructure concessions. However, infrastructure projects are projects to long-term and therefore exposed to various uncertainties.

Fourth, giving a project a concession and then having constant requests for economic rebalancing is not beneficial for the government or anyone else. Especially when the requests lead to lawsuits that take years to be resolved. A concession involved in legal claims delays economic growth generates dissatisfaction in society and increases the burden on the government.

Taking into account the above aspects and the importance of solving them, this thesis intends to answer the following research questions:

a. What is the importance of using more flexible evaluation methodologies in the evaluation of infrastructure projects?
b. Can flexibilities and uncertainties change the value of public infrastructure projects?
c. What are the characteristics of concession contracts for public infrastructure projects?
d. What are the main problems affecting public infrastructure concessions in Brazil?
e. What characteristics/factors affecting or can influence the success of a concession?
f. What are the similarities and differences in infrastructure PPPs contracts in the Latin America and Caribbean region?

g. What can be done to prevent governments from bearing contingent liabilities?
h. How to make infrastructure projects attractive to private investors, but without generating budgetary costs for the government.

1.2. Objectives

1.2.1. Main Objective

Analyze how the main contractual clauses formulated in public infrastructure contracts impact concessions and can lead to both failure and success, using the Real Options Approach to determine the factors and flexibilities capable of attracting private investment without generating costs for the Granting Authority.

1.2.2. Secondary Objectives

i. Review existing literature on the use of the Real Options Approach in the valuation of incentives and clauses in public infrastructure concession contracts.
ii. Analyze the characteristics of concession contracts for public infrastructure projects in Brazil that can influence and contribute to effectiveness or failure, particularly in the main sectors that drive economic development.
iii. Analyze what strategies, similarities, and differences Latin American and Caribbean countries, share in the formulation of design contracts and Public-Private Partnerships.
iv. Develop a model capable of mitigating demand risk in public infrastructure projects without creating contingent liabilities for the granting authority.

1.3. Main Contributions

The results of this thesis are of interest both in the academic and practical fields.

For academics and researchers, it contributes to advancing knowledge about evaluating infrastructure projects, through new strategies capable of incorporating flexibility. The Real Options Approach emphasizes the importance of using flexible evaluation methodologies.

As for the practical scope, the results of this thesis generate useful knowledge for public managers, public policymakers, private companies, and the community. From a public policy perspective, this thesis makes significant contributions by offering actionable recommendations, innovative strategies, and a deeper understanding of the factors that influence the success of infrastructure concessions. Policymakers can leverage these contributions to enhance the effectiveness, sustainability, and overall impact of public infrastructure projects.

The research outcomes can serve as a valuable resource for policymakers to make informed decisions related to infrastructure concessions. By providing a comprehensive analysis of the key determinants for success and proposing innovative strategies, this thesis equips policymakers with the knowledge needed to navigate complex challenges in the infrastructure sector.

Finally, this these provide guidelines to support the government in the selection of mechanisms capable of contributing to the success of concessions and ensuring equitable allocation of risk without causing liabilities to the parties.

1.4. Delimitation and Research Methodology

The delimitation of the study area of this thesis is the infrastructure projects developed in Latin America and the Caribbean. Specifically, concessions for public infrastructure projects in the airport and road sectors incorporate flexible clauses in their concession contracts in Brazil.

The theoretical delimitation of the research is restricted to the areas of Valuation and Real Options. The Real Options Approach was chosen due to its ability to incorporate flexibility and adapt to situations of high uncertainty.

The research methodology comprises three basic phases: i) qualitative study, ii) applied-quantitative research; and iii) conclusive phase. The first phase of the qualitative study, comprises: i) a bibliographic review stage, of the research themes; ii) documentary review stage: referring to concession contracts for the highway and airport sectors; and a content analysis of Public-Private Partnerships in Latin America. The second phase, quantitative-applied stage, involves the development and valuation, using Real Options Approach, of a strategy capable of reducing demand risk (thus encouraging private participation) without imposing a budgetary burden on the government.

In the last phase, the conclusive phase, conclusions were drawn about the research objectives, the study limitations and suggestions for future work.

Figure 1.1 presents the research design.

1.5. Structure of the Thesis

This thesis consists of six chapters, where, chapters 2 to 5 aim to answer one of the secondary objectives. Therefore, each chapter contributes to achieving the main objective.

After this introduction. Chapter 2 deals with the literature review. Chapter 3 presents a detailed review of the concession contracts signed in Brazil and the main problems that led to the failure of the concessions. Chapter 4 exposes the characteristics of Public-Private Partnerships in Latin America and shows an investment trend (mandatory trigger). Chapter 5 presents a model developed as a proposal to solve the problem of falling demand. The proposed model is validated using data from the International Airport of Rio de Janeiro (Galeão).

Finally, chapter 6 presents conclusions, indications of research limitations and suggestions for future research.

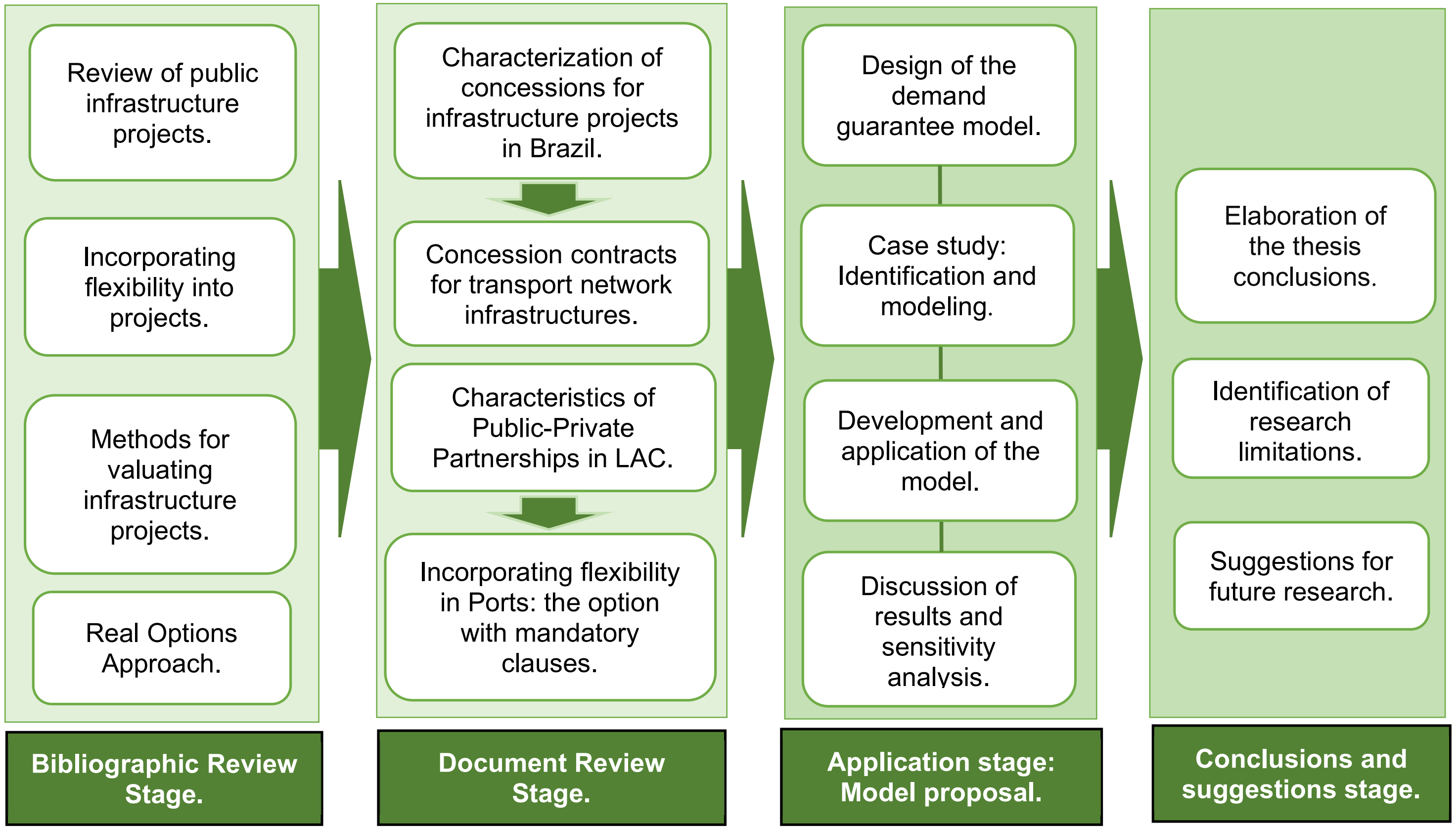

Figure 1.1 – Research design and its components

2
Real Options Approach in Public Infrastructure Projects: A Review of the Literature

Many academic publications are addressing the use of Real Options Approach (ROA) to evaluate infrastructure projects. Several of these papers include review chapters with valuable contributions and explanations of the use of models and techniques of ROA valuation (Rose, 1998; Chiara et al., 2007; Shan et al., 2010; Liu et al., 2017; Carbonara and Pellegrino, 2018). However, these articles do not perform a detailed review of the literature. In most cases, the reviews focus only on the specific type of option being valued in the article or are limited to specific aspects of ROA valuation. Regarding the review papers, highlights the paper by Martins et al. published in 2015. The paper of Martins et al. (2015) provides the trajectory of the emergence of ROA, relates how and why ROs appeared, its main characteristics, similarities and differences from Financial Options, the main types of options, and their valuation techniques. Although Martins et al. (2015) made significant contributions to the field, a more exhaustive and complete review of the area still needs to be carried out. In addition, few studies are addressing only public infrastructure projects.

Therefore, this chapter aims to present a detailed review of academic literature on using ROA in the valuation of public infrastructure projects. In addition to the traditional option valuation, this review includes papers modeling government support as options. In total, we reviewed 39 papers published in high-impact journals. For our analysis, we extract relevant information, such as authors, the public project analyzed, study objective, type of concession contract, option/guarantee type, valuation method, uncertainties analyzed, and type of analysis performed. The results allow us to know the main advances made in the area, current trends and opportunities for future research.

This chapter is structured as follows. Section 2.1 describes the infrastructure projects and their valuation method. Section 2.2 briefly explains the theory of Real Options and the types of options. Section 2.3 describes the review methodology.

Section 2.4 shows the main results of the review. Section 2.5 presents the valuation of traditional options and Section 2.6 the valuation of government support.

2.1. Infrastructure Projects and Valuation

Investment in infrastructure differs from other types of traditional investments because they represent investments in projects that are essential for society (Brandao and Saraiva, 2007), required significant capital, are long-term projects, have a long period of economic recovery, are dynamic and irreversible (Krüger, 2012). Consequently, the public sector often does not have the resources or the financial, technical, or operational capacity to invest in infrastructure. Therefore, it recurs agreements with private partners to be able to supply its infrastructure needs. Unfortunately, several uncertainties and risks affect the success and development of this type of project. This, in turn, impacts the attractiveness of the projects for the private partner. To make them attractive, the public sector grants certain government support.

Discounted Cash Flow (DCF) is the most widely used method for valuing any type of investment. This method consists of discounting future cash flows to present value. The Net Present Value (NPV) is the most used indicator to determine whether the investment is profitable or not (Regan et al., 2015). According to this method, a project is financially viable and should be accepted whenever the NPV is positive and greater than zero. According to Krüger (2012), investment decisions in infrastructure projects are mainly based on two criteria: i) Net Present Value, through cost-benefit analysis; and ii) political considerations. The advantages of using DCF are simple to understand, clear decision criteria, practical, does not require much computational effort, takes into account the time value of money, and allows the comparison between several investments (Regan et al., 2015).

The DCF method is suitable when the future is foreseeable. That is, when there are no uncertainties that affect the project or whenever the risks throughout the life of the infrastructure project remain stable (Garvin and Cheah, 2004). This method, despite being the most used method, does not capture the risks and uncertainties that affect projects. Thus, a passive position is assumed. The flexibility that managers have to respond and adapt to impacts of uncertainties or deviations from the initial scenario is not considered (Panayi and Trigeorgis, 1998).

Furthermore, the NPV and DCF do not take into account the irreversibility characteristic of investments in infrastructure projects (Regan et al., 2015).

Consequently, even though DCF and NPV are good instruments to evaluate investments when there is a long-time horizon, the investment is irreversible and there are many risks, more adaptive and flexible approaches are needed. Therefore, ROA is the best way to evaluate projects with future uncertainty (Polat and Battal, 2021). Furthermore, it provides a more realistic analysis of a project's value compared to the DCF method.

2.1.1. Government Support

Infrastructure concessions are seen as incomplete contracts because not all future uncertainties and risks can be specified in ex-ante contracts, increasing the perception of risk by the private sector (Krüger, 2012). To attract the private sector's capital, the public sector may offer different types of flexible contracts and incentives, such as subsidies, guarantees, direct capital contributions, or other alternative forms of government support (Cheah and Liu, 2006). According to Iyer and Sagheer (2011) the main types of government support are minimum traffic guarantees, shadow tolls, exchange rate guarantees, grants and subordinated loans, concession extensions, and minimum revenue guarantees.

As these supports represent different degrees of risk mitigation, the type of support granted depends on the type of risk involved. On the other hand, they can also represent liabilities for the government. In this context, two significant problems arise to face. The first is to determine the level of viable support/guarantee to be granted, and the second is to calculate its value for both the private partner and the government. Assessing the cost of the support allows the public sector to determine future budgetary impacts. Moreover, it allows the definition of optimal guarantee levels, which are high enough to encourage private participation but low enough not to overburden the government (Brandao and Saraiva, 2008; Carbonara et al., 2014).

To solve these problems is necessary a quantitative assessment of risk. Guarantees and other types of government support can be interpreted as options because the obligations associated with these types of incentives are triggered when certain conditions previously established in the contracts are reached (Cheah and

Liu, 2006). After being triggered, it is at the discretion of the holder whether they will be exercised or not. Therefore, they are rights (in the hands of their holders) and no obligations. Due to these characteristics, it is more appropriate for its valuation to use real options instead of traditional methods (Ashuri et al., 2012; Brandao and Saraiva, 2007, 2008).

2.2. Real Options Approach

The Real Options Approach (ROA) allows for incorporating flexibility in decision-making management and capturing the impact of uncertainties. Real options theory has its origins in the work of Black and Scholes and Merton (Black and Scholes, 1973; Merton, 1973). However, was Myers in 1977 who first coined the term real options (Chiara et al., 2007; Polat and Battal, 2021). According to Myers, there is an analogy between a future investment and a financial option, as both represent a right and will only be exercised if they are profitable (Martins et al., 2015). Like financial options, Real Option represents a right but not an obligation. Furthermore, options can be of the *call* (buy) or *put* (sell) type. Depending on the exercise date, they can be of the European type (only exercised at maturity) or American (exercised on any date until maturity).

The Real Option (RO) differs from the financial option due to the following characteristics: i) first, the real option refers to real assets while the financial option refers to financial assets (Polat and Battal, 2021). Investing in a real asset can be considered an option if: i) flexibility and uncertainty are incorporated into the valuation process (Zapata Quimbayo et al., 2018); ii) the investment allows future cash flows; iii) the option cannot be sold to third parties. For example, infrastructure projects are not traded on a secondary market. However, although they cannot be sold or traded, the investment opportunity has value (Krüger, 2012). In a changing environment, if managers identify and use options to adapt to future flexibilities, then, greater uncertainty can lead to greater value (Martins et al., 2014). In this way, a project with RO is much more valuable than one without RO. It is noted that flexibility, in addition to adding value, also comes at a cost. This cost can be in terms of time, money, or complexity (Garvin and Cheah, 2004).

Considering different forms of incorporating flexibility, the literature distinguishes the following types of real options (Martins et al., 2015):

- Option to defer: pertains to the possibility to postpone or delay an investment in order to gather additional information (Cruz and Marques, 2013). This option is advantageous in infrastructure projects where the investment capital is costly, limited, and substancial;
- Timing option: gives the possibility of delaying the investment until finding the most favorable moment to make it. This option is similar to the defer option (Kozlova, 2017);
- Stage investment option: involves making investments in several stages. Each stage can be independent, or the next stage can be conditional on the construction of one or more previous stages. In case of an unfavorable perspective on the future, the option allows not to invest in later stages (Martins et al., 2015). In infrastructure projects, phased construction allows managers to learn more about market conditions over time. This way enables less expensive responses (Garvin and Cheah, 2004);
- Option to abandon: when the investor decides to exit the investment. Having this option is very important for the investor when the future is not good or profitable. According to Huang and Chou (2006), this option reduces risk and increases the concessionaire's decision flexibility;
- Option to change scale: This allows for the reduction or expansion of the scale of the project (Kozlova, 2017). In infrastructure projects, the concessionaire could expand the infrastructure when the conditions are favorable (e.g., increased demand);
- Option to switch: this option gives the flexibility to switch between various products or modes of operation (Martins et al., 2015);
- Option to grow: this option implies that current investments create the opportunity for future investment. This option is considered a compound option because its value depends on a pre-existing option. According to Garvin and Cheah (2004), investments in infrastructure create future investment and growth opportunities. Martins et al. (2015) also indicate that growth options commonly involve a sequence of investments;
- Interacting option: implies the possibility of combining one or more of the previous options.

Valuation using the Real Options Approach falls into two main categories: continuous-time models and ii) discrete-time models. Each of the categories has different implications for modeling techniques (Garvin and Cheah, 2004). Regarding the Real Option pricing process, the first step, is to define the sources of uncertainty. The second step is to model the development of uncertainty variables. According to the literature, the Geometric Brownian Motion (GBM), the Mean Reversion Process (MRP), and the Binomial Trees are the most used models to model uncertainties. Depending on the uncertainty variable, it is possible to include modification (e.g., the inclusion of jumps in an MRP process). Finally, the option value is calculated. The three most used techniques to evaluate options are Partial Differential Equations (PDE), Binomial Trees, and Monte Carlo Simulation – MCS (Kozlova, 2017; Martins et al., 2015), defined as follows:

- PDE allows the evaluation of options in continuous time. The best-known method is the Black-Scholes-Merton (BSM) model (Regan et al., 2015). Its main advantage is the simplicity and speed of calculating the option value. The most prominent disadvantages are the fact that it does not allow the valuation of compound options, admits only one source of uncertainty, and is only useful for the valuation of European options. Furthermore, the formula lacks transparency and is difficult to interpret (Martins et al., 2015; Regan et al., 2015);
- The Binomial Tree is a discrete-time model. In this model, flexibility is modeled as a tree structure (Garvin and Cheah, 2004). The mathematical formulation is simple. Starting from the initial value, for the next period the value of the asset will move up or down (in both cases multiplied by a probability). At each period, the asset can only assume one of these possible values (Martins et al., 2015). This model is very easy to use when there is only one uncertainty variable. However, as the number of variables and the period increase, the model may suffer a "Curse of dimensionality" (Regan et al., 2015). As an advantage, this model can be used to value European or American options. In the American type of option, it simplifies the process of retroactive induction;
- The MCS is a simulation model and allows for dealing with various uncertainties. Calculates the option value by simulating several possible future scenarios for the uncertainty variables (Regan et al., 2015). This method creates a distribution of the possible expected future values of the Project (Kozlova, 2017). The main advantages are ease and simplicity both

in its use and in its interpretation. It is also useful for solving path-dependence problems (Martins et al., 2015). As for the downside, it is computationally expensive.

It is easy to use in European-type options, as the option is exercised on the expiration date, which requires a forward induction procedure (Garvin and Cheah, 2004). For American-type options, which can be exercised at any time up to the expiration date and therefore require a backtracking procedure, it can be cumbersome to use or seem incompatible (Garvin and Cheah, 2004). Therefore, the MCS would need to be coupled with other methods (for example generic algorithm) or determine a finite number of exercise opportunities (for example Bermuda options) (Regan et al., 2015).

Finally, it should be noted that real options can be categorized as “on” or “in” projects. They are “on projects”, when various types of exogenous flexibilities (abandonment, postponement, change) can be used to evaluate investment opportunities. In turn, “in projects” are those projects when design flexibilities are endogenous and allow adaptation to changing environments (Chiara et al., 2007; Cruz and Marques, 2013).

2.3. Review Methodology

Figure 2.1 illustrates the flowchart of the literature review process. We started the process by searching the Scopus and Google Scholar databases. We used the keywords “Infrastructure”, “infrastructure projects”, “infrastructure investment” and “Real Options.” For a more exhaustive search, we used these same keywords in Spanish and Portuguese. According to Trigeorgis and Tsekrekos (2018), a long analysis period allows the identification of trends in the literature. Therefore, the review was restricted to papers published between 2000 and March 2021. We also excluded the type of documents: book, book chapter, conference review, and conference paper.

Next, we carried out a quick inspection of the abstracts and selected only those papers that refer to public infrastructure projects (such as roads, airports, hospitals, ports, and others). To work with high-impact papers and ensure reliability, we arbitrarily decided to select only those papers cited more than 20 times or/and are published in journals with an Impact Factor equal to or greater than 1.5. In this way, we reached a final set of 39 papers.

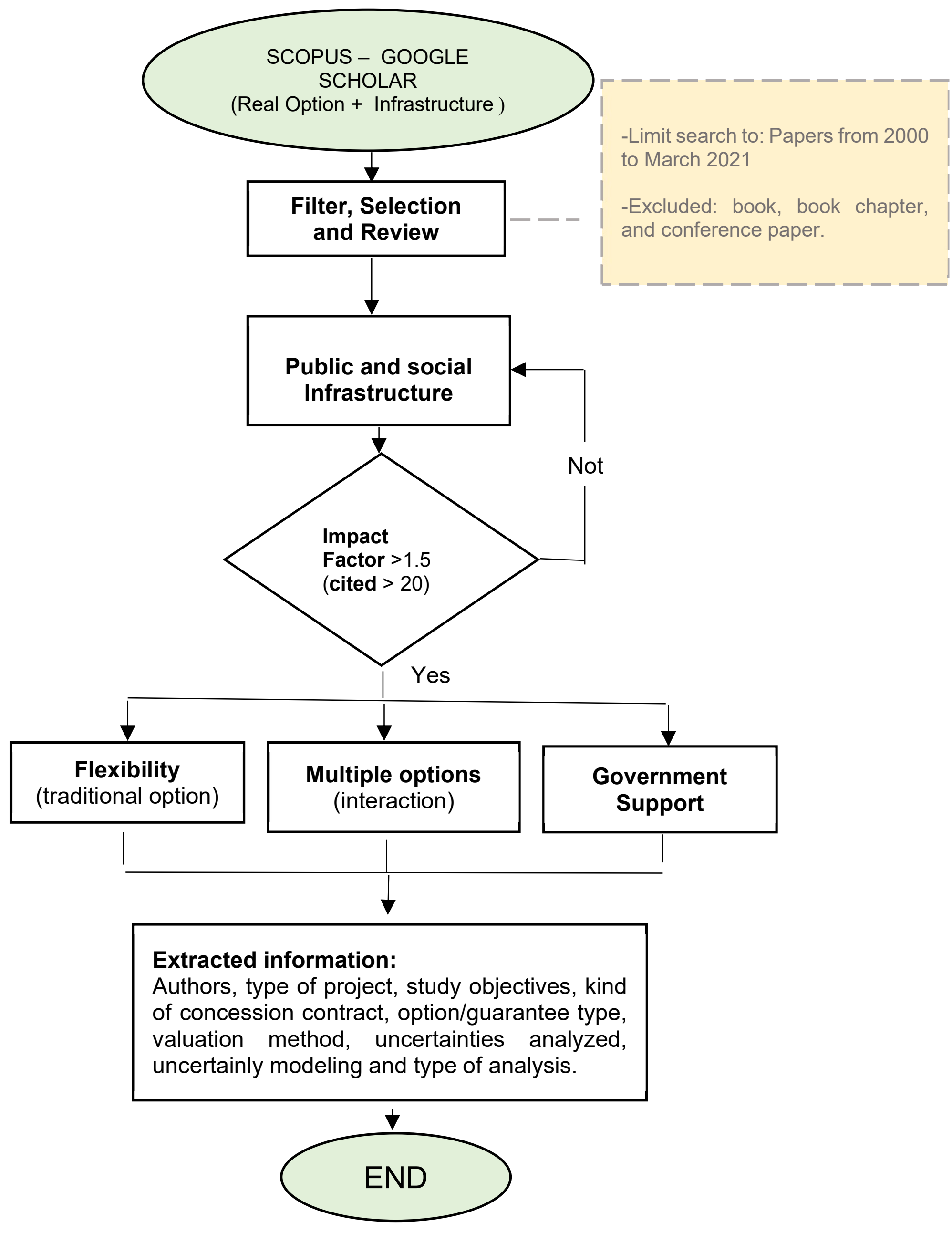

Figure 2.1 - Flowchart of the literature review process

Then, we grouped the 39 final papers according to the type of option they analyzed: whether the paper analyzed traditional options or government support or the interaction between traditional options and government support. Finally, for a more detailed analysis, we follow the method proposed by (Kozlova 2017). Thereby, in each paper, we extracted the following information: authors, year of publication, sources, country, the project analyzed, type of project, study objectives, kind of concession contract, option/guarantee type, valuation method, uncertainties analyzed, uncertainty modeling and type of analysis (for two or more options). In Appendix 1 details the summary of this analysis.

2.4. Applications of Real Options Valuation in Infrastructure Projects

2.4.1. Main Trends

Figure 2.2 illustrates the number of papers that address the use of ROA in the valuation of social infrastructure projects. This figure reveals that there is a growing positive trend of publications over the years. In the last decade (from 2011 to 2021), there has been an increase in publications compared to the period of 2000-2010.

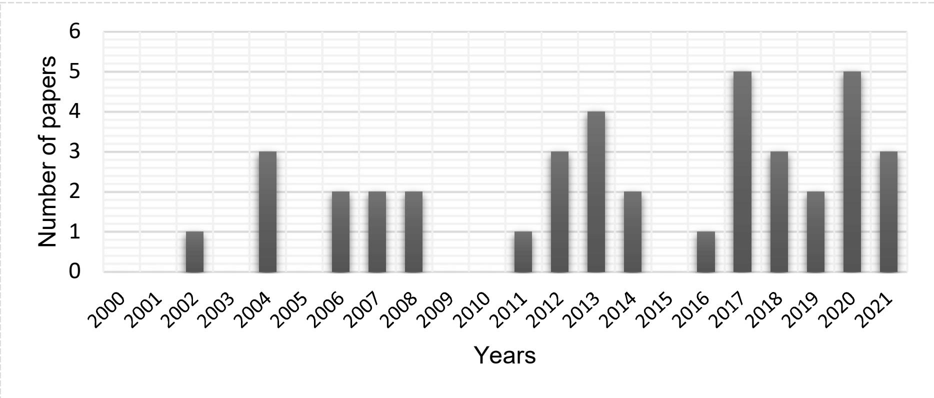

Figure 2.2 – Scientific production on ROA in the valuation of social infrastructure projects by year of publication

When analyzing the papers by types of data sources used, we observed that 67% of the papers reviewed used data from cases of the Real Infrastructure Project (Real Case) and identified the project name and the country; 20% used data from simulated or hypothetical projects, and 13% did not mention. Notice that there is a tendency to study clauses (mandatory or flexible) incorporated in infrastructure concession contracts in several countries. We also observe a tendency to investigate cases of developing countries. Mainly because developing countries have the greatest infrastructure deficits either due to lack or because they do not have the necessary capacity. These trends reflect that research addresses real-world dynamics and problems.

The main application of RO in the valuation of infrastructure projects is focused on projects of transportation networks. Toll Road-type infrastructure projects are the most analyzed, followed by the airport, the Highway, and Ports (See Figure 2.3). The main goal is to support public policymakers and governments with evidence and scientific studies that show the optimal way to assign flexibility and government support. The valuation of infrastructure projects with ROA can provide information on the effectiveness, successes, and failures in allocating concession contracts. For example, this evidence is crucial for developing countries, most of which do not have large public budgets to develop infrastructure and need private participation.

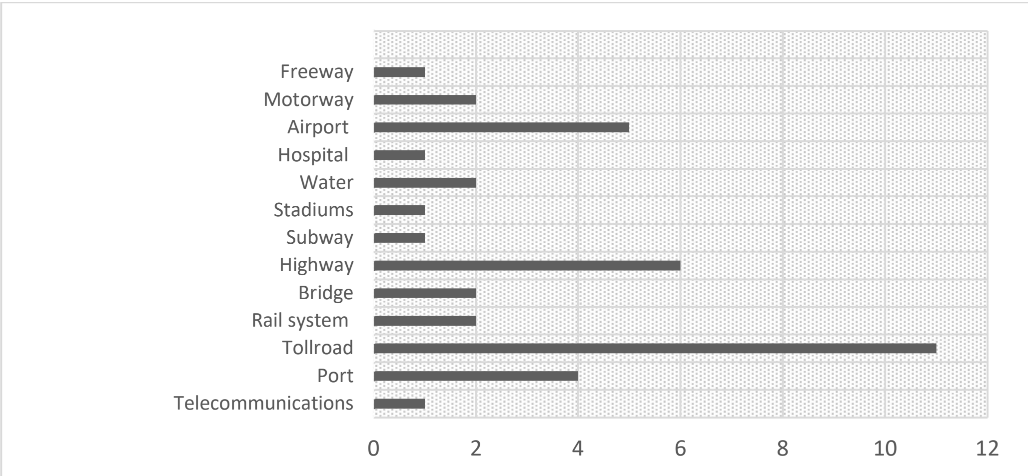

Figure 2.3 – Types of infrastructure projects

2.4.2. Uncertainty Sources

Table 2.1 shows the types of uncertainty identified. We note that the main source of uncertainty is demand. Demand uncertainty is divided into traffic (66%), demand (10%, for other types), and as a result in revenue uncertainty (7%).

Some researchers identify the uncertainty of demand based on the demand for capacity (D'Halluin et al., 2002), the number of attendees at a stadium (Cabral and Silva, 2013), and the number of patients in a hospital (Cruz and Marques, 2013). Others identify revenue uncertainty (Bowe and Lee, 2004; Huang and Chou, 2006). Revenue uncertainty is the consequence of demand (when forecast demand deviates from initial expectations). Forecasting demand is almost impossible, especially for long periods, as it depends on multiple factors. For this reason, demand continues to be the main uncertainty modeled by the researchers.

Table 2.1– Uncertainty sources in infrastructure projects

Types of uncertainty	Number of times identified.	Percentage
Demand:	35	85 %
- Traffic	27	66%
- Revenues	7	17%
- Price	1	2%
Cost	1	2%
Operation and maintenance (O&M) expenses.	3	7%
Climate risk	2	5%

Table 2.1 also identifies other types of uncertainties. Park et al. (2013) point out that, unlike other PPPs, Operation and Maintenance (O&M) expenses are the main sources of uncertainties in water and sewer systems concessions. The authors model the O&M expenses uncertainty and propose two mechanisms to guarantee the adequate allocation of risks: Maximum Revenue Limit (MRL) and Maximum Expense Limit (MEL). The MRL has exercised annually to avoid an increase in the annual tariff. The MEL represents the maximum total amount in O&M expenses that the private partner will assume. Ihm et al. (2019) also analyze the case of a Water infrastructure, specifically a dam that provides fresh water to several cities in South Korea through a water supply system. In this case, the authors identify climate risk (drought) as the main source of uncertainty. Kim and Li (2020) also identify the uncertainty of climate risk. The authors analyze how long the construction of a highway should be postponed since there are already other means of transport (barges and air transport). According to the authors, the decision depends on weather conditions.

2.4.3. Uncertainty Modeling

The paper's review proves that the most used techniques in the infrastructure area the Geometric Brownian motion (GBM) and the Binomial tree (See Figure 2.4). Demand, rates, and costs cannot be negative, so researchers often use GBM to model this type of uncertainty. The use of the Binomial tree is mainly due to its simplicity of application.

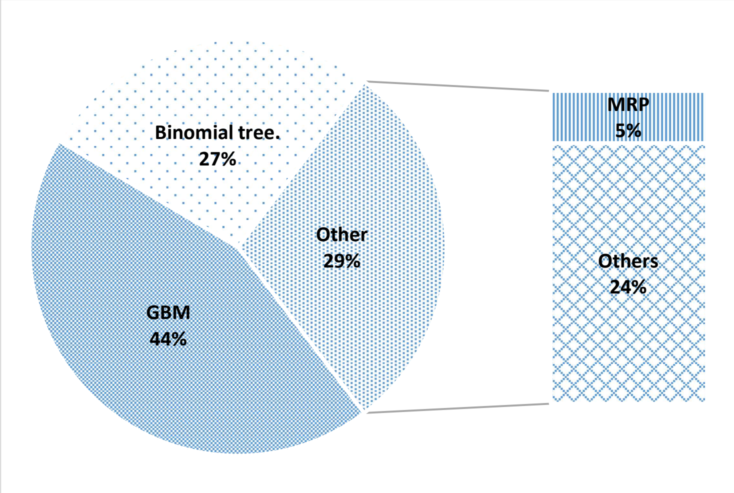

Figure 2.4 – Modeling of uncertainty sources

Unlike most, Zapata Quimbayo et al. (2018) use two statistical tests (the unit root test and the variance ratio test) to test the use of GBM or the Mean Reverting Process (MRP). Their results show that traffic can exhibit mean reversion behavior. However, the authors manifest that this result may be a consequence of the periodicity of the data. A monthly periodicity could show seasonal characteristics. Higher periodicities, such as the annual one, may not show seasonality. Therefore, the GBM would continue to be adequate to model uncertainty. Doan and Menyah (2013) also use MRP to model traffic uncertainty. In this case, the authors justify the use of MRP because traffic demand cannot grow beyond the capacity of the toll road. Although Operation and Maintenance (O&M) expenses are usually considered a percentage of capital costs, the authors argue that O&M expenses are higher during the initial and final phase of the period of operation. Thus, the future evolution of O&M expenses follows a stochastic process and can be modeled with a GBM. Finally, Attarzadeh et al. (2017) use fuzzy triangular numbers to represent the uncertainty of the traffic volume. The Fuzzy theory is applied to represent the subjective judgments of the decision-makers regarding uncertainty modeling.

2.4.4. Real Option Valuation Techniques

Figure 2.5 shows the evaluation techniques most used in the papers reviewed. Researchers frequently use Monte Carlo Simulation (MCS) to assess options. The review indicates that there is a tendency to analyze the interactions between the options. When there is more than one option, researchers analyze the effect of one option on the other. When there is only one option, researchers look at the optimal time to exercise the option and the size of the option value. Figure 2.6 shows the researchers' goals. Although there is a tendency to determine the value of options, there is also a growing interest in calculating the level. Both the level and the joint level/value calculation are predominantly observed in the valuation of government support.

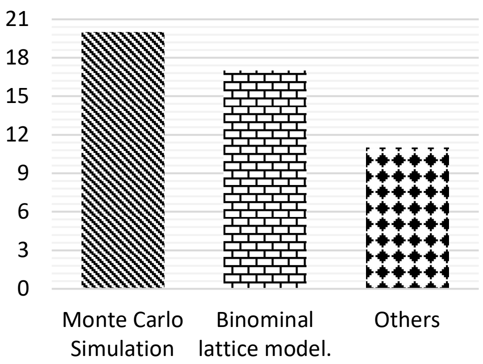

Figure 2.5 – Valuation Methods

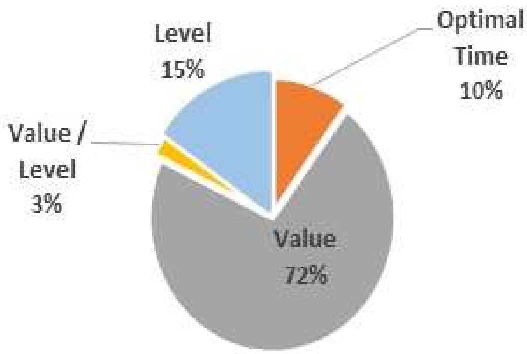

Figure 2.6 – Calculated Variables

2.5. Traditional Options in Infrastructure Projects

In infrastructure projects, researchers incorporate flexibility in two ways: with traditional options or with government support. Table 2.2 shows that the option of infrastructure expansion (35%) is the most analyzed relative to traditional options. In second place is the option to defer or delay the construction (19%), followed by the option to invest (15%), and finally by the option to abandon (12%). Although all the options should be evaluated before starting the project to be included in the concession contracts, not all have the same exercise period. The options to invest, abandon, and defer construction are evaluated to be exercised primarily in the early stages of the project or even before signing the contract. In this line, Doan and Menyah (2013) argue that before considering granting any type of subsidy or guarantee, the option to defer should be evaluated.

The expansion option can be evaluated either before the project starts or during its operational phase. However, if the expansion´s trigger is located in the final phase of the project, implementation is unlikely. Unless extra incentives are provided, such as extending the concession period. In general, expanding the project requires additional investments. When the project is nearing the end, the time available to recover the additional investment is shorter. Unlike other papers that evaluate expansion options in transportation networks, Cruz and Marques (2013) analyze an expansion option in a Healthcare infrastructure.

Table 2.2 –Types of Options

Option/ guarantee type	Number of times identified.	Percentage	
Traditional Option			
Deferral or delay payments option.	1	4%	2%
Defer or delay option (physical infrastructure)	5	19%	9%
Optimal timing	1	4%	2%
Invest Option	4	15%	8%
Expand option	9	35%	17%
Contract option	1	4%	2%
Option to cancel early the concession	1	4%	2%
Abandon option	3	12%	6%
Multi-stage growth options (compound real option).	1	4%	2%
Subtotal	26	100%	49%
Government support as an option			
Minimum Revenue Guarantee (MRG).	9	33%	17%
Subsidy	3	11%	6%
Minimum Traffic Guarantee (MTG)	1	4%	2%
Traffic band (traffic floor and traffic cap).	1	4%	2%
Minimum Demand Guarantee (MDG).	2	7%	4%
Maximum Revenue limit (MRL).	1	4%	2%
Maximum Expense limit (MEL).	1	4%	2%
Participation loans.	1	4%	2%
Early fund generation (EFG) option.	1	4%	2%
Guaranteed revenue (MinMax-GR option).	1	4%	2%
Maximum Revenue Cap (MRC).	1	4%	2%
Term extension policies.	1	4%	2%
Warranty	1	4%	2%
Availability payments (APs)	1	4%	2%
Flexible-term contracts	1	4%	2%
Optimal concession term.	1	4%	2%
Subtotal	27	100%	51%
Total	**53**		**100%**

By incorporating flexibility, some researchers analyze the option itself and evaluate the implications of that option. For example, Balliauw et al. (2020) study the relationship between the size and the optimal investment time in expanding additional capacity. Balliauw and Onghena (2020) also highlight the importance of incorporating a flexible investment calendar (time and size together). Bowe and Lee (2004) use real data from a Rail system to evaluate three types of options (expand, contract, defer). The authors conclude that: i) a prior real option alters the value of the asset and the value of subsequent options; ii) a later option increases the value of the asset and the previous options; iii) the interaction of multiple options, for the most part, makes their values not additive. The impact of the interactions on the value of the Project depends on the combinations between their relative degree of being "in or out-of-the-money," type of option (put-call), the correlation between options, exercise date, and the sequence in which they can be exercised.

Other types of options are also analyzed, although less frequently. Martins et al. (2014) study the case of an investment option by stages (New Lisbon Airport). The authors use Monte Carlo simulation to evaluate the option of building in phases every ten years (built modularly). Polat and Battal (2021) study the case of a compound option. The value of this option depends on another option that can occur in a row or simultaneously depending on the project.

The incorporation of options is also used to evaluate political and economic implications. Pimentel et al. (2020) analyze the impact that the use of real options has on the EU's co-financing policy, mainly on the co-financing rate. Cabral and Silva (2013) study the case of a stadium and propose an alternative to optimally allocate public funds to minimize public participation and maintain attractiveness for the private investor.

2.6. Valuation of Government Support as an Option

Table 2.2 presents the types of government support that can be priced using ROA. Concession contracts more frequently incorporate Minimum Revenue Guarantee (MRG). Therefore, this is one of the types of support most studied by researchers (33% of the total government support studied), followed by Subsidies (11%) and Minimum Demand Guarantee (7%).

In the Minimum Revenue Guarantee (MRG), the government commits to compensating the possible deficits resulting from the difference between a predetermined revenue level and the real revenue level (Huang and Chou, 2006). This encourages the private sector to invest. In this modality, the guarantee can be exercised at different discrete points during a predetermined time horizon (Chiara et al., 2007). Instead of making a payment at the beginning, the government distributes its payments throughout the life of the concession (Brandao & Saraiva, 2007). According to Chiara et al. (2007), the structure of a revenue guarantee can take various forms. The nature of the guarantee is determined when two elements are established: i) the number of times the guaranteed party has the right to exercise the guarantee; ii) the dates on which the rights can be exercised. In general, guarantees are like put options because the government provides them. The guarantees can be exercised several times within a time interval during the concession term. However, Brandao and Saraiva (2007) indicate that if they are of the annual exercise, they are formed by a series of independent European options.

However, the MRG only limits the risks for the private sector and does not limit the high returns (Carbonara et al., 2014), generated when the volume of traffic is greater than pre-established. To avoid giving too much to the concessionaire, the government can counteract excessive earnings by introducing additional repayment obligations such as requiring a reduction in the tariff, placing a limit on tariff to benefit users, and increasing taxes (Attarzadeh et al., 2017; Cheah & Liu, 2006). Another alternative is to determine a demand or revenue ceiling, above which the concessionaire has to transfer part of the revenue (surplus) to the government (Brandao and Saraiva, 2007). Many researchers have addressed this issue and developed models to find the optimal limits. Carbonara et al. (2014) structure MRGs that allow determining the level of guarantees that balances the needs of the private sector and the needs of the public sector. The authors develop a model based on real options to find the revenue cap (the minimum amount of revenue secured by the government). Ashuri et al. (2012) develop the binomial lattice RO risk-neutral model to value MRG options. The authors also evaluate the Toll Revenue Cap (TRC) option for an adequate distribution of risks. Both options are analyzed as compound options, and the effect of their interactions is valued. Buyukyoran and Gundes (2017) propose an approach to limit the excesses of MRG by introducing a Maximum Revenue Cap (MRC). The authors seek to determine the lower limit of MRG and the upper limit of MRC both as compound options. Their objective is to identify the fair values of the combination of options. Carbonara and Pellegrino, (2018) develop a methodology to establish a “win–win” condition between both partners (private-public) so that the risk is distributed fairly. The authors determine the revenue floor (the minimum amount of revenue secured by the government) and revenue ceiling (the upper threshold of revenue that defines the excess revenue to be shared).

Other authors, instead of analyzing the MRG, analyze the Minimum Traffic Guarantee (MTG). Although they appear similar, the MTG would be more applicable when analyzing transport networks because it depends specifically on the traffic volume. It should be noted that, when modeled, the MTG has the same operation as the MRG. As with MRG, in an MTG, researchers also discuss the need for stable limits. Brandao and Saraiva (2008) use RO and develop a model to evaluate the value of the MTG. Their objective is to analyze the cost-benefit and propose alternatives to limit the government's exposure. In the proposed model, the caps limit the government's exposure ensuring that a specific amount of subsidy is not exceeded. The authors manifest that the choice of limits depends on the size of the project, the maximum exposure that the government can tolerate, and the impact on the MTG. Iyer and Sagheer (2011) propose a traffic band to mitigate and equitably share demand risk. The traffic band is a combination of traffic floor and traffic cap. The authors state that although these floor-ceiling options are mutually exclusive, both can coexist.

Another way to encourage private participation is to provide subsidies. Subsidies can be granted at the beginning of the construction of the infrastructure or on certain specific dates throughout the concession period (although usually during the early years). Defilippi (2004) analyzes which concession alternative (mono or multi-operator in the port of Callao in Peru) would be more beneficial for Peruvian society. The author also evaluates the suitability of grant subsidies. Brandão et al. (2012) analyze the case of a subway system to evaluate the effect of subsidy payments and a Minimum Demand Guarantee (MDG) on the value and risk of the project.

The concession period extension is another form of government support, with the difference that it does not represent a liability for the government. However, it does not avoid demand risks or low revenue. Marques et al. (2021) analyze three alternatives to extend the concession term to encourage expansion. According to the authors, considering the extension of the term will allow the concessionaire to cross the Brownian Bridge. Unlike other articles that consider traffic demand a trigger for expansion, the authors consider economic viability as a trigger. The authors conclude that only the expansion policy with penalty allows an anticipated investment in expansion.

Lara-Galera et al. (2016) develop a methodology based on OR to quantify the value of the participation loans for the concessionaire, that is, to quantify the real cost for the public sector. The participatory loan is also analyzed as a form of government support. In a participatory loan contract, the interests paid by the concessionaire depend on the volume of traffic (optional). In other words, the lender receives a variable interest that depends on the evolution of the traffic (activity of the borrower). When the traffic volume is low (high), the administration subsidizes the financing (shares the revenue through a higher interest).

Besides all, the study of the interactions of various types of options was also carried out. Huang and Chou (2006) analyze the interactions of combining MRG with the option to abandon. The results showed that both MRG and the abandonment option could create value in a single-option formulation. On a compound option valuation, the combination of MRG and abandon option counteract each other, and therefore their values decrease. Increases in one of the options lead to a reduction in value in the other option. Alonso-Conde et al. (2007) analyze two options and their interaction. The first is the option to defer payments to the government (when the IRR is less than 10%). The second is the option to terminate the concession early (when the IRR is greater than 17.5%). The interaction shows that when the value of option 1 increases, option 2 is less likely to be triggered (they have a negative effect on 2). Jin et al. (2021) analyze the interactions between the concession period and MRG to determine their values simultaneously. The results show that the duration of the concession period is inversely proportional to the level of MRG. The longer the concession period, the lower the MRG level.

3
Analysis of Concession Contracts for Infrastructure Projects in Brazil: Problems, Solutions, and New Challenges

One of the fundamental drivers of a country's economic development is the effective development of its infrastructure. The success of an infrastructure concession depends on various factors, including the ability to attract private investment without imposing excessive burdens on the granting authority. Contractual clauses that share the risk of demand fluctuations can serve as incentives to attract private investment. However, capital investment in infrastructure projects is subject to significant uncertainties and often fails to achieve the expected results. This suggests that if poorly designed, concession clauses can create problems, such as increasing budgetary expenditures, requests for financial rebalancing, or even the return of the concession to the government.

Numerous academic studies have addressed the issue of concessions and PPPs. Suárez et al., (2020) and Suárez Alemán et al. (2020) conducted comparative analyses of the concession characteristics across several countries. In the literature, most papers focus on solving specific problems, such as financing, guarantees/subsidies analysis, cost of capital, and demand risk. Nevertheless, as far as we know, no study analyzes the factors leading to concession projects' failure.

The objective of this chapter is to provide an analysis of the key characteristics of concession contracts in Brazil and the problems that have led to the failure of concessions. This study focuses on the land mobility and airport sectors due to their importance in economic development, and the fact that with over 2,500 airports Brazil has the second greatest number of airports in the world (Netherlands Enterprise Agency, 2020). A total of 112 concession contracts were analyzed in two stages. The first stage (ex-ante) involved a detailed examination of the contractual clauses included in the concession contracts signed between the Government (as the granting authority) and its private partners (the concessionaires). Which were auctioned between 1995 and 2022. Second (ex-post), the concessions that had issues were examined and analyzed to verify which specific characteristics of the contracts contributed to the problems identified. This study also detailed which strategies have been used to solve these problems and identify the challenges that still need to be resolved.

One of the primary contributions of this chapter is to provide an overview of concession contracts, presenting both their characteristics and their evolution over time. By identifying the main problems that led to the failure of the concessions, this work allows comparisons of similarities and differences across different sectors. In addition, it helps identify the factors that require greater attention and control. This study contributes to the development of new measures and mechanisms to enhance the efficiency of concession contracts.

This chapter is organized as follows: Section 3.1 describes the sectors analyzed. Section 3.2 describes the methodology and Section 3.3 details the main characteristics of concession contracts and PPPs. Section 3.4 discusses the main problems that led to the failure of the concessions. Finally, Section 3.5 shows the results.

3.1.
Infrastructure and Economic Development

In simple terms, a Concession can be defined as a contract between the Government and a private company to manage or exploit a specific good or service for a specific period. Public-Private Partnerships (PPPs) are contracts involving a public entity (government) and a private for-profit entity, in which, each party plays a role in producing public goods or services in return for receiving some benefit. In recent years, concessions and PPPs have gained importance as they provide a solution for governments to meet their infrastructure and public service needs.

Two sectors are perceived as fundamental for economic development. The land transportation infrastructure sector is perceived as the driver of development, and the airport sector is considered the thermometer of economic activity. Concessions are important instruments for the development of these types of infrastructure. Brazil is one of the pioneers in implementing PPPs and has been developing this model steadily over the last decades.

The Federal Highway Concession Program began in 1993, with the first group of concessions auctioned in 1994. In 1996, the Delegations Law was enacted, allowing states to include stretches of federal highways in their concession programs. In 2001 a land transportation regulatory agency responsible for exploring the federal highway infrastructure, the Agência Nacional de Transportes Terrestres (ANTT), was created. In 2007 the second group of concessions was auctioned, the third group of concessions taking place in 2013 and the fourth in 2018 (ANTT, 2022). In addition to these groups, over the years, the Brazilian government has also auctioned other highway infrastructure projects.

As of 2023, there have been seven rounds of airport concessions, starting in 2011, and then in 2012, followed by further rounds in 2014, 2017, 2019, 2021, and finally in 2022. With this, 91.6% of all airport passenger traffic has already been concessioned.

3.2.
Methodology

The selection of the concession contracts for inclusion in the database of this chapter involved three distinct stages: Document availability, Delimitation stage, and Analysis. The diagram describing the selection process is presented in Figure 3.1.

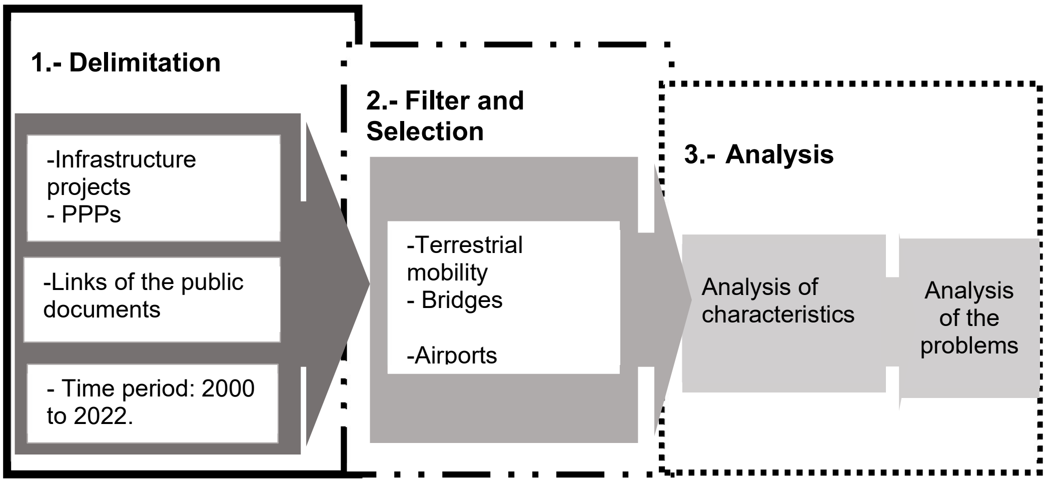

Figure 3.1 – Scheme of the selection process and analysis of concession contracts

Each stage is described in detail below:

1. *Availability*: concessioned projects that make their contractual documents virtually available.
2. *Delimitation*: projects from the sector of land mobility, bridges, and airports signed between 1994 and 2022.

3. *Analysis*: for the analysis of the characteristics of the contracts, the following information was extracted: date of signature and end, entity (state or federal), model and name of the project, type of project, the criterion for judgment of the auction, premium or discount, concession term, risk sharing, expansion trigger, current situation, and problems. For the analysis at this stage, Concessions with problems are defined as those with excessive requests for economic and financial rebalancing; those with an amicable termination of the concession contract or are in the re-bidding stage; those in the process of litigation before the court for compensation; and finally, those that were returned to the granting Authority.

The steps mentioned above resulted in the selection of 112 concession contracts. Appendix 2, details the information obtained from each of the contracts.

3.3. Characteristics of Concession Contracts

Of the 112 contracts analyzed, 88 were concession contracts celebrated by the Federal government and 24 by State governments. Figure 3.2 shows the distribution by Federal entity and by State. The State of São Paulo has the largest number of PPPs contracts.

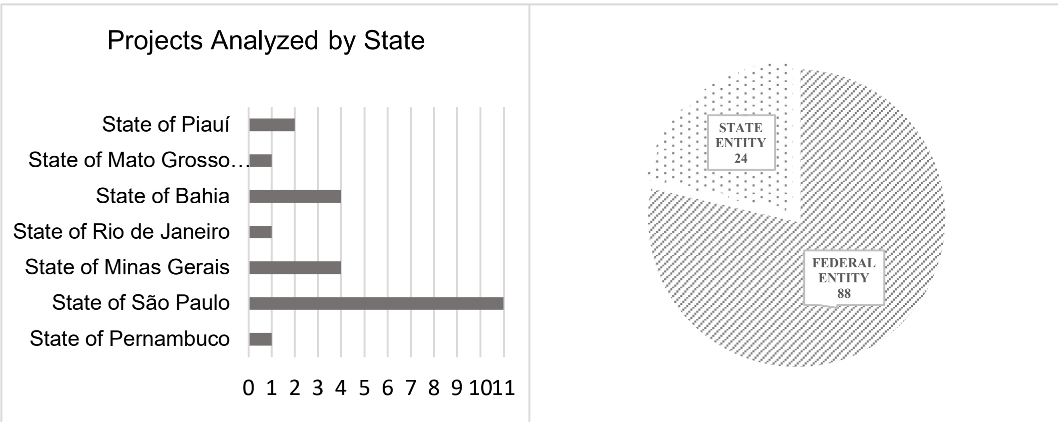

Figure 3.2 - Contracts analyzed by entity and state

On average, the concession term is 30 years. An extension of the concession term is allowed to restore the economic and financial balance. In some cases, the extension of the term is at the exclusive discretion of the granting authority. However, in most cases, a maximum limit of years is allowed.

Table 3.1 – Risk sharing in State Concessions

Entity	Project	Risk Sharing
State of Pernambuco	Rota dos Coqueiros/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band.
State of São Paulo	Linha 4 – Amarela/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band (6 years).
State of Minas Gerais	Rodovia MG 050/ Sponsored Concession	Sharing the risk of non-realization of demand: by toll revenue bands.
State of São Paulo	Linha 6 – Laranja/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band. (10 years). Geo-ecological risk, Risk of interference.
State of Rio de Janeiro	VLT Carioca/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band (10 years).
State of Bahia	Projeto Metrô de Salvador e Lauro de Freitas/ Sponsored Concession	Sharing of financial gains. Sharing the risk of non-realization of demand: by demand band. The liquidation agent deficit risk.
State of São Paulo	Linha 18 – Bronze (modal monotrilho)/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band. Geo-technological Risk, Risk of interference.
State of São Paulo	Rodovia Tamoios (3a etapa) / Sponsored Concession	Sharing the risk of non-realization of demand: by revenue bands.
State of São Paulo	SIM - Sistema Integrado Metropolitano (modal VLT) / Sponsored Concession	Sharing the risk of non-realization of demand.
State of São Paulo	Linha 05 Lilás e Linha 17 (Monotrilho) Ouro – Metrô/ Common Concession	Sharing the risk of non-realization of demand: by demand band. Exchange protection mechanism.
State of Bahia	Projeto Sistema Rodoviário BA052 (Estrada do Feijão) / Sponsored Concession	Sharing the risk of non-realization of demand.
State of Bahia	VLT / Monotrilho de Salvador/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band. Exchange protection mechanism.
State of Bahia	Projeto Sistema Rodoviário Ponte Salvador - Ilha de Itaparica/ Sponsored Concession	Sharing the risk of non-realization of demand: by demand band (15 years). Exchange protection mechanism
State of São Paulo	Linha 08 Diamante e Linha 09 Esmeralda de Trens metropolitanos/ Common Concession	Sharing the risk of non-realization of demand: by demand band. (20 years).
State of Minas Gerais	Aeroporto Regional da Zona da Mata (ARZM)/ Sponsored Concession	Sharing of Tariff Revenues, with the Granting Authority, in case of excess demand.

3.3.1. Risk Allocation and Sharing

Most concessions carried out by state governments have risk-sharing mechanisms. Table 3.1 exhibits the state concessions that present sharing. Demand risk is the main risk shared between the concessionaire and the granting authority. This sharing is carried out through demand bands. On the one hand, the granting authority attempts to subsidize projects if demand is too low. On the other hand, it also seeks to limit excessive earnings if demand is high. For this, it includes a demand ceiling above which revenues must be passed on to the granting authority. The risk sharing of demand by bands is mainly observed in sponsored concessions.

The demand bands determine how much the granting authority must pay to the concessionaire or how much it will receive back. The result depends on the comparison between projected demand and actual demand and/or projected revenue and actual revenue. The result is directly related to monetary compensation. If demand is low, the concessionaire, receives additional compensation for the demand reduction. However, if the demand exceeds the ceiling limits, the granting authority must appropriate this value.

The Zona da Mata Regional Airport (ARZM) is the only one that has a different sharing mechanism, which involves revenue sharing. Thus, the concessionaire receives a monetary payment to make investments. However, over the years, if the demand is high the revenues are shared with the granting authority.

Table 3.2 – Risk sharing in Federal concessions

Project	**Risk Sharing**
BR-364/365/MG/GO - Uberlândia a Jataí Rodovia Ecovias do Cerrado	Risk sharing mechanism related to Service level maintenance Works.
BR-101/290/448/386/RS Rodovias Integradas do Sul - ViaSul	
BR-101/SC - Paulo Lopes a São João do Sul. Rodovia CCR ViaCosteira	
Rodovias BR-153/TO/GO, BR-080/GO, BR-414/GO /Rodovia Ecovias do Araguaia	Exchange Protection Mechanism: for the first 5 years. Risk Mitigation Mechanism.
BR-116/465/493/RJ/MG Rodovia EcoRioMinas	Exchange Protection Mechanism: for the first 5 years. Input Price Risk Sharing Mechanism.
Sistema Rodoviário BR-163/230/MT/PA Rodovia Via Brasil	Mitigation Mechanism (tariff revenue risk mitigation): Applicable to the last 3 years of the concession. (Between eighth and tenth year).
CCR Rio/SP (RJ) – São Paulo (SP)/ Sistema Rodovia Federal	Exchange Protection Mechanism: for the first 5 years.

In federal concessions, none of the airports has risk-sharing mechanisms. Table 3.2 presents the federal highway concessions that share risks. Unlike the other highways, the Via Brasil highway is the only one that has a mitigation mechanism for demand risk. However, the mechanism applies to the last 3 years of the concession term. Although federal highway concessions do not include demand sharing (Except for Via Brasil), they do include other types of sharing. Exchange protection mechanisms are observed in some federal and state concessions, mainly applicable in the first five years.

3.3.2. Expansion Triggers

All contracts administered by the federal government include expansion clauses. Highway concessions include the volumetric trigger clause and airport concessions include the investment trigger. The triggers can only be activated up to a maximum of 5 years before the end of the concession term.

The volumetric triggers of federal highways refer to activities and services aimed at expanding the capacity of the highway system to maintain the level of service. The triggers are conditioned to the volume of traffic, the execution depends on whether the trigger is reached or not. Primarily, these involve construction work to implement additional lanes in stretches or sub-stretches on the road.

Table 3.3 – Risk sharing of works started with a trigger

Highways With Volumetric Trigger	No Burden Sharing	With Burden Sharing
BR 116/324/BA 526/528- Via Bahia	*	
BR-050/GO/MG - ECO050	*	
BR 101/ES/BA - ECO101	*	
BR 060, BR 153 e BR 262 DF / GO / MG - CONCEBRA	*	
BR-153/TO/GO- Galvão BR-153	*	
BR-163/MT - BR-163 e MT-407 - Rota do Oeste	*	
BR-040/DF/GO/MG - VIA 040	*	
BR-163/MS - MS VIA	*	
BR-101/RJ-ECOPONTE	*	
BR-364/365/MG/GO - Ecovias do Cerrado		*
BR-101/290/448/386/RS ViaSul		*
BR-101/SC - Paulo Lopes a São João do Sul -CCR ViaCosteira		*
Rodovias BR-153/TO/GO, BR-080/GO, BR-414/GO - Ecovias do Araguaia	*	
BR-116/465/493/RJ/MG - EcoRioMinas	*	

In general, once the trigger is activated, it will only constitute a contractual obligation of execution if ANTT authorizes it. If ANTT authorizes the execution of the works, but the concessionaire does not comply with the expansion, ANTT will apply the penalties provided for in the contract, through a Tariff discount. This procedure applies to all roads with triggers, but there are some exceptions. Table 3.3 shows contracts with construction cost risk-sharing clauses or not. The Ecovias do Cerrado, ViaSul, and CCR ViaCosteira highways are the only ones that have a mechanism for sharing the risk burden between the granting authority and the concessionaire.

On the other hand, all Airports concessioned by the ANAC have an investment trigger. The trigger is activated whenever the analysis demonstrates excess demand on airport capacity. The trigger applies to Phase II, in which the Concessionaire must comply with the obligation to maintain the service level. The concessionaire is responsible for submitting the Infrastructure Management Plan to ANAC. In this plan, the concessionaire identifies the traffic levels that constitute the trigger.

The exceptions are airports granted in the 6th Round (2021) and the 7th Round (2022). They contain three triggers instead of one. All apply to Phase II and are also based on demand. However, the only one that has the trigger fixed is the one in the passenger terminal (85% of passengers at peak hours). Table 3.4 presents the list of airport blocks with three triggers.

Finally, projects granted by state governments do not include expansion clauses.

Table 3.4 – Blocks and Airports with Three Investment Triggers

Round	Airports per Block	Triggers
6ª Round (2021)	Block Sul: 9 airports	**Investment Trigger** (applicable in Phase II). ***Investment Trigger in Passenger Terminals**: When peak hour passenger demand reaches 85%. ***Investment trigger in track system**: When the demand for aircraft movement gives rise to the need to make investments in the track system. ***Investment trigger in aircraft yards**: When the demand for aircraft movement gives rise to the need to make investments in aircraft yards
	Block Norte: 7 airports	
	Block Central: 6 airports	
7ª Round (2022)	Block Aviação Geral: 2 airports	
	Block Norte II: 2 airports	
	Block SP/MS/PA/MG: 11 airports	

3.3.3. Auction Judgment Criteria

The most used concession models in infrastructure projects are the common concession and the sponsored concession. Projects granted by state governments mostly use the sponsored concession model where the objective is to attract private investors to projects that have low demand by offering monetary compensation. However, the objective of the states is to pay the smallest amount of compensation possible. In public auctions, state governments establish a maximum compensation limit. Therefore, bidders' bids must be less than this maximum limit, and the criterion for judging the auction of sponsored concessions is the lowest value of the monetary compensation.

In Appendix 2, we observe that in sponsored concessions the discount (maximum compensation limit minus bid by the winning bidder) was small. The winning bidders' bid was only slightly less than the upper limit or is the same as the upper limit.

Regarding the common concession, the federal government makes a distinction regarding the auction criteria between airports and other infrastructures. Typically, Airports use the highest bid criterion, while highways and bridges use the lowest basic toll fare criterion. In this case, the winning bidder is the one offering the lowest fare or the greatest discount on the fare. The government establishes the fare, and the auction is carried out based on it. Over the years, the discounts offered by bidders were very aggressive.

In 2021 and 2022, a new road auction criterion began to be used: the hybrid criterion. This auction criterion is jointly composed of the lowest basic toll fare and the highest bid value. The granting authority establishes the limit discount on the fare. First, the bidders bid on the basic fare discount. In case of a tie (all offer the limit discount), the criterion of the highest grant value is used as a tiebreaker. The highways that have used these auction criteria are CCR Rio/SP, EcoRioMinas and Ecovias do Araguaia.

Regarding the airports granted by the federal government, we observed that all of them also recorded very aggressive premiums. With premiums greater than 100% (premium= positive difference between the bid offered vs the base amount established in the notice). From 2011 to 2013, the criterion was the highest global fixed bid value. Thus, the concessionaire was obliged to pay the granting authority annual/monthly installments of fixed contribution (installments of the global grant) and a variable contribution on gross revenue. The airports that were auctioned with this criterion were those from the first, second, and third rounds.

Airport concessions made in 2017 (4th round) changed to the criterion of the highest initial fixed bid offered. In this criterion, the contribution to the system includes both fixed and variable contributions. The fixed contribution is constituted by the initial fixed contribution (initial fixed grant auctioned) and the sum of the annual fixed grant (grant that is not auctioned, but that is established in the notice). In these contracts, the auction is based on the parcel of the initial fixed contribution. The winning bidder must pay this amount when signing the concession contract.

Since 2019, the airport concessions belonging to the 5th, 6th, and 7th rounds used the criterion of the highest initial bid offered. The total contribution to the system is only formed by the initial and variable contribution. The initial contribution is the criterion for judging the auction and must be paid to the system upon signing the contract. The variable contribution is paid based on revenue and according to a system of rates. This last auction criterion closely resembles the one used in the 4th round, with the difference that everything offered (all the offered grants) has to be paid at the beginning.

In contrast to previous rounds, concessions began to be in airport blocks. Over the years, the value of the premium has always been high, but in rounds 5 and 6, these values reached an exceptionally elevated level, exceeding 1000%.

Finally, state governments that used the common concession model did not differentiate between types of infrastructure. The main criterion for judging the auction was the highest bid.

3.4. Main Problems in Concessions

Appendix 3 characterizes land mobility projects that presented problems and the factors that generated these problems. Nevertheless, very few concessions were effectively returned to the granting authority. The return processes are not automatic and generate complicated legal problems. As can be seen in the table, the main problem was the non-realization of the forecasted demand, followed by the difficulty in obtaining financing. The Linha 6- Laranja de São Paulo and the federal highways Concebra, Galvão BR-153, and Rota do Oeste registered as one of the main problems the non-release of financing from the BNDES. The reason for not releasing the financing was that the partners of the concessionaires were being investigated by the Lava-Jato case, which was a federal investigation into corruption schemes.

The concessionaire companies of the Autopista Fluminense, Via Bahia, MS Via, and VIA 040 highways prioritize the problem of non-realization of the forecasted demand. Although each project indicates a specific problem as the most important one, it is observed that they all faced the same problems. Such as difficulty in obtaining financing, failure to meet projected demand, accumulation of debts being the fines the main factor, not carrying out the works within the contractually agreed deadlines, financial constraints, stoppage of the project, and problems with contract modeling.

Unlike the other cases, where the problem was the drop in demand, either due to modeling errors or as a result of the macroeconomic scenario, MS Via emphasizes that its problem was the drop in demand due to competition. According to MS Via, the demand on the highway has decreased due to competition with another transport system parallel to the highway. The concessionaire says that the railway modal implemented in Rondonopolis (MT) parallel to the highway, reduced the traffic on the road and generated losses for it.

Another concession that signaled the same problem was the Rota do Oeste. Unable to meet its investment obligations, the Concessionaire attempted to sell the control to another group. However, this operation did not proceed because of the authorization of the extension of the railroad from Rondonópolis to Lucas do Rio Verde (MT). This authorization caused the prospective new company to withdraw and no longer express interest.

Regarding ECO 101, the concessionaire argued that its problems were associated with the terms stipulated in the contract. Notably, Line 18- Bronze was the only project that was terminated for completely different reasons. The State of São Paulo terminated the contract because a Bus Rapid Transit (BRT) system was deemed to be a more viable option than the originally planned Monorail modal.

Table 3.5 shows the main problems registered by three of the most important Brazilian airports: Natal International Airport (Natal/RN), Viracopos International Airport (Campinas/SP) and International Airport of Rio de Janeiro (Rio de Janeiro/RJ). These airports are in the process of negotiations for the re-bidding of the airports or reaching an agreement to terminate them. The contract termination process is not automatic and depends on the government's decision. Furthermore, the contract clauses do not contemplate the possibility of a return to the government. Therefore, this process involves legal disputes. The main allegation of the concessionaires was that the actual demand turned out to be significantly lower than the expected demand, which led the concessionaires to default on fulfilling their obligations. Mainly the not complying with the grant payments. Other problems include the impact of the macroeconomic crisis and errors in the concession modeling.

Table 3.5 – Problems in airport concessions.

Project	Situation	Problems
International Airport of São Gonçalo do Amarante - NATAL (RN)	In 2020, it was declared in the process of Rebidding (Decree No. 10,472/2020) The rebidding through the amicable termination of the concession contract. In the study stage.	Inframerica announced the forfeiture of the concession, due to: *Frustration of demand projection expectations. *Projected demand of 4.3 million, actual registered demand of 2.3 million passengers. *Criticisms on the structure and design of the airport. * Difficulties in maintaining long-term airport operations. * Impact of reduced tourism and economic crisis. * Boarding fees are 35% lower when compared to other airports. *Default with obligations (grant, BNDES, others).
International Airport of Viracopos (SP)/ CAMPINAS	Since 2017, the concessionaire has expressed its desire to return the concession, through a friendly devolution mechanism. In the process of re-bidding: Decree Nº 10.427, of July 2020.	The concession presented problems from the beginning. *Non-realization of demand projections. * There was an overestimation of demand. *There was an oversizing of the terminal, with no justification for the demand. *Obligation to make high investments in the first years, of the Football Cup. *High value of the grant offered by the winning concessionaire. *Inability to comply with obligations to pay the fixed annual contribution (grant).
International Airport of Rio de Janeiro/Galeão – Antônio Carlos Jobim	In June 2022, the rebidding was approved in the 21st Federal CPPI. The re-bidding process at the study stage.	The main problems affecting the airport concession are: *Gradual transfer of international flights to Guarulhos Airport (GRU). *Airport considered a White Elephant. *Predatory competition with Santos Dumont. *Precarious accessibility and lack of urban mobility. *Drop in demand. *Problems and economic crisis at a general level. *Contracts requiring high initial investments. *Covid-19 pandemic. *Problems in modeling the concession.

A notable fact that draws attention is that the criterion for judging the auction was the highest annual fixed grant amount, which turned out to be very high. Premiums of over 150% were observed on the amounts specified in the bid documents. In the case of the International Airport of Rio de Janeiro (Galeão), the premium was nearly 400% higher than the base amount. Another fact is that the airports were classified as important for the 2014 World Soccer Cup, and therefore, they demanded significant investments in the initial years (as mandatory investments) to be ready at the beginning of the Cup.

3.5.
Results and Discussion

Appendix 2 reveals that there are many similarities in all the contracts, although differences exist from one sector to another. The criterion for judging the auction is one of the most obvious distinctions. Risk-sharing is also different, but this characteristic is fundamentally tied to the type of concession: common or PPP. Expansion clauses or mandatory expansions of works are fundamentally related to demand triggers. However, in the highway sector, the trigger is defined in the contract. In the airport sector, only the last contracts have defined triggers.

In the review of the contracts, it can be observed that all the clauses are based on the static analysis of the demand and the project. Uncertainties that may arise during the life of the concession are not incorporated. Brandão and Saraiva, (2008) pointed out that the evaluation with traditional methods does not allow evaluating the flexibility of the project, mainly because traditional methods do not consider the effects of uncertainties. Therefore, it is suggested that the real options approach is the best way to evaluate this type of project.

3.5.1.
Highway Concessions

First, the main shared risk is demand risk. In the revised contracts, the state governments incorporate risk-sharing mechanisms for the non-realization of demand: through a demand band. This involves facing two challenges: determining the appropriate level of risk sharing between partners and determining its duration.

In addition, it also needs to be analyzed how efficient is the risk-sharing mechanism per demand bands. This review reveals that the granting authority is not entirely risk-averse. It may even be willing to assume a part of the risk so that the infrastructure is developed in favor of the social benefit. Therefore, before determining the limits of the demand band, it is imperative to assess whether the granting authority is assuming more risk than the private investor. There is a possibility that the government is fully subsidizing the project's risk, eliminating any risk for the private investor. In that case, the question arises regarding the benefits of utilizing Public-Private Partnerships. Furthermore, if the granting authority has to shoulder high liabilities, the question arises about the appropriate strategy to assume these liabilities without generating a budget deficit.

The second interesting point is the implementation of clauses with investment triggers. With this mechanism, the granting authority tries to oblige the concessionaire to maintain a good level of service when demand is high. However, triggers depend on demand, which is not always constant and predictable.

Although the expansion policies contained in the contracts reviewed in this study do not represent heavy investments, it is important to analyze whether they are adequate. For example, if a trigger were activated but demand subsequently decreased, the expansion would still need to be carried out even with low demand. This directly influences the concessionaire's decision on whether it is beneficial to expand or to be punished (with fare discounts), depending on which option represents a lower cost for the concessionaire. Therefore, there is a need to analyze when an increase in demand truly represents a sustained rise justifying the expansion. On the other hand, the burden-sharing mechanism is useful when the concessionaire seeks to make the expansion a contractual obligation. However, determining the appropriate level of burden-sharing is also crucial.

Finally, the high percentage of discount observed in highway auctions may result from the Lowest Basic Toll Fare criterion. Without a maximum discount limit, companies can bid aggressively without real support. Aggressive bids can be the result of overly optimistic perceptions or obeying the particular interests of the bidding companies. The issue arises when concessionaires win the auction and then seek ways to increase the value of the tariffs. Often through claims for economic and financial rebalancing.

The implementation of the new judgment criterion, the hybrid criterion, aims to limit aggressive bids in the auction. Therefore, the current challenge is to determine the optimal discount limit. Choosing a random cap still allows bidders to bid up to the full cap and then attempt to increase the tariffs. There is a BNDES proposal to establish a clause that obliges the concessionaire to make an additional capital contribution for each 1% discount offered (BNDES, 2021). However, this represents a double impact on the long-term revenue flow (income reduction plus grant payments). Thus, there are two challenges to solve: i) the adequate level of the discount limit, and ii) identifying complementary mechanisms to mitigate aggressiveness.

In summary, when analyzing the problems that led to the failure of the concession or the sale of control to another company, we perceived that everything is a chain effect. A holistic review points out that an aggressive bid together with the inability to obtain financing leads to delays in works, requests for extensions in the construction of mandatory works, and the accumulation of fines.

When performing a division into groups (between causal factors and consequence factors), we observed that the error in demand modeling added to the opportunistic behavior of bidders leads to aggressive bids. The aggressive bids, added to the difficulties in obtaining financing, led to delays in the works. These in turn lead to requests for deadline extensions. Which finally leads to the accumulation of fines and the stoppage of the project. The accumulation of fines together with other factors leads to requests for the return of concessions, the sale of control, and legal proceedings.

The challenges in obtaining financing depend on the solidity of the concessionary bidder and its reputation. The financial solidity of the bidder can be easily filtered in the concession notice, excluding those lacking the capacity to secure financing. Nevertheless, the reputation factor is more complex. For instance, if the concessionaires that had difficulty in obtaining financing from the BNDES were not involved in the Lava Jato investigation, they might have been able to obtain financing from other sources.

To solve the problem of predatory demand, as experienced by Rota do Oeste e MS VIA, the granting authority tendered the Via Brasil highway (a highway with the same section as the two with problems) with a concession term of 10 years. Additionally, It added the demand risk-sharing clause for the last 3 years. The strategy to eliminate predatory competition is to auction the highway with shorter terms compatible with the entry into operation of the Ferrovia Ferrogrão.

3.5.2. Airport Concessions

The review of airport concession contracts showed that the main problem issue lies in accurately predicting passenger demand, which constitutes a modeling error. Additionally, It is observed that concessionaires frequently have difficulties in carrying out the mandatory works, generating delays and fines. Failure to pay grants generates a chain effect, such as the accumulation of debts which over time become unpayable.

Like highways, excessively high premiums are observed in airport concessions. At this point, it is important to analyze the reason behind this, if it is solely due to a very optimistic projection of the future, or if it is some other particular interest of the bidder. For example, at the Viracopos and the Rio de Janeiro/Galeão airports, there was an oversizing of the terminal and high premiums, without justification of the demand.

A holistic analysis showed that the criterion of a higher initial fixed grant value can also be a factor causing problems. If there is a very high premium payable in full upon contract signing, then in subsequent years, the concessionaire may encounter difficulties in meeting its commitments. Airports auctioned before 2014 had to make heavy investments in the first years to be operational for the World Cup. This requirement for an initial investment may also have conditioned the long-term viability of the project. That is the obligation of a high grant added to strong investments, particularly in the early years, conditions the subsequent cash flows especially when demand is low.

The 6th round recorded extremely excessive premiums. Therefore, if the motivation for these high premiums is not the optimistic projection or opportunist, another possible factor could be that the base value of the auction (the value indicated in the notice) is low or shows errors in modeling. Remember that this base value is the reference point for the bids.

A particularly interesting case is that of Rio de Janeiro/Galeão Airport. This airport faces a dual problem. On the one hand, the demand for international flights is absorbed by Guarulhos airport in São Paulo. On the other hand, demand for domestic flights is absorbed by Santos Dumont Airport (also in Rio de Janeiro). As a result, the overall demand for Galeão is diminished. This predatory competition is fueled by factors such as the lack of access to urban mobility in Galeão, among other factors. The review shows that the same problems may be present in other airports, such as: i) Congonhas vs Guarulhos in São Paulo; ii) Confins vs Pampunlha, in Minas Gerais.

As a measure to avoid predatory demand, the government planned to auction Santos Dumont Airport together with Galeão Airport. This would result in a single company would operate both terminals. According to specialists, while this new strategy eliminates the problem of predatory competition, it also raises concerns about potential monopolistic behavior. Regarding the idea of a monopoly, there is the question of whether concessions in blocks can also generate a monopoly on tariffs.

Finally, it is noted that both in highway concessions and in airports there is a very important topic to be discussed: indemnity to the concessionaire in the case of giving up. Thus, the need arises for indemnification mechanisms that can help mitigate opportunistic behavior by the concessionaires.

4
Overview of Capital Investments in Latin American Infrastructure: the case of the Option with Mandatory Clauses

Infrastructure projects require significant capital investment. Excessive costs, delays, irreversibility, and financial obstacles are common characteristics of this type of investment. As a result, many governments cannot afford to develop public infrastructure or build, maintain, and repair the existing infrastructure. To address these challenges, Public-Private Partnerships (PPPs) agreements have been widely used as a solution for countries to meet their infrastructure needs, with the participation of the private sector (Martins et al., 2017; Vassallo, 2018).

However, public infrastructure development through PPPs agreements is subject to several types of risks, such as technological, economic, political, social, and environmental risks. According to Martins et al. (2017), the most important of these is the demand risk, which leads to a high probability of renegotiating contracts. In addition, some projects present managerial flexibilities, which allow for changes in their operational strategy to maximize returns and minimize losses. These flexibilities can have an impact on the project.

Analyzing risks, uncertainties, and the impact of any managerial and operational flexibilities can make projects more attractive to private investors and allow parties to improve their decision-making process and results. Managerial flexibility can enhance the value of a project that is subject to one or more sources of uncertainty (Martins et al., 2017). Flexibility can be incorporated at various project stages, such as planning, design, and evaluation. Demand uncertainty, for example, which results from the difficulty of forecasting future demand, can be managed more efficiently by incorporating flexibility. Flexibility allows the analysis of several alternatives regarding the optimal investment moment, optimum construction time, and the optimal physical capacity of the infrastructure.

This chapter presents the main characteristics of PPPs concession projects in Latin America and the Caribbean (LAC) region. We analyzed trends in several countries and projects and studied the possibility of incorporating flexibility. Next, we detail the mechanisms currently used to mitigate port demand risk. Finally, we present the concession of the Terminal Portuario Multipropósito de Salaverry in Peru as a case study to show how uncertainty can be addressed by incorporating managerial flexibility into contracts.

This chapter is organized as follows. Section 1 contains the introduction. Section 2 analyzes PPPs in Latin America. Section 3 describes the main problems and challenges of PPPs in the region. Section 4 details the characteristics of investment in stages. Finally, Section 5 shows the investment strategy depending on demand and the case of the option with mandatory clauses.

4.1. Financing Infrastructure Projects in Latin America

As it is well known, infrastructure is fundamental for economic development. A good infrastructure system in different sectors, which is efficient and effective, promotes the well-being of society. Several researchers argue that there is a positive correlation between investment in infrastructure and growth. Therefore, an increase in infrastructure development contributes to increases in the economic growth of a country or region (Serebrisky et al., 2015).

Globalization and free trade agreements have recently encouraged trade dynamics, which has driven the need to develop transport systems infrastructure (Defilippi, 2004). This indicates that there is a relationship between developmental transport networks and trade. Therefore, below, we detail some types of transport infrastructure and their situation in the LAC region.

One of the key transport network infrastructures is Ports. Port infrastructure allows the integration of different modes of transport and acts as an interface between producers and consumers. In addition, they are a fundamental part of the international maritime transportation system and have great relevance within the logistics system of a country because it is a facilitator of trade (Balliauw et al., 2019a; Martins et al., 2017; Taneja et al., 2010a; Wilmsmeier and Monios, 2016).

Since the 1990s, ports in LAC moved from a state scheme in which the project is owned and operated by the government or by a state-owned firm to a Landlord Port model. In the Landlord Port model, the government maintains ownership of the infrastructure. However, it cedes the operations and/or administration to the private sector. Private port participation through PPPs agreements has generated many benefits, mainly greater operational efficiency and productivity (Suárez-Alemán et al., 2020).

For this reason, LAC ports are predominantly operated through PPPs schemes. The development of port terminals through PPPs contracts in Latin America has increased significantly in recent years. Suárez-Alemán et al. (2020) showed that 77% of cargo in Latin America is handled by ports built through PPP contracts, 15% in private ports, and only 8% in state ports. Of 189 ports in Latin America that handle containerized cargo, 119 operate under a PPPs scheme. As the size of the port increases, port PPPs gain more importance. Figure 4.1 shows the number of port under the PPPs scheme in Latin America and the Caribbean region.

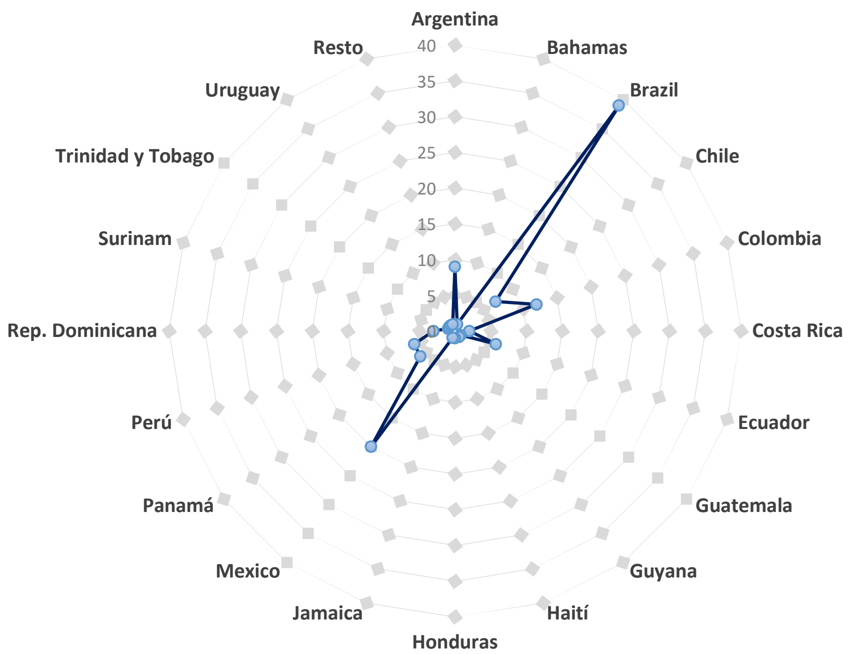

Figure 4.1 – Ports under the PPPs scheme in Latin America and the Caribbean
Source: Suárez-Alemán et al., (2020)

According to Suárez-Alemán et al. (2020), the port infrastructure projects in LAC developed through a PPPs contract have the following characteristics: First, the concessions are carried out through public bidding. For the classification of the bidders, specific requirements were also established, such as the minimum operating experience, the minimum value of shares owned, the minimum rating of long-term debt, and the minimum shareholding. The main adjudication criteria are a higher investment, higher government payment, lower construction or operation costs, and lower tariffs. However, in Latin America, the main criterion is the highest payment to the government, including a fixed part and a variable part based on income, followed by the lowest tariff for users. All these criteria can be used individually or in combinations. Second, the percentage of payment to the government varies and is composed of fixed and variable parts depending on the total revenue: number of units mobilized, revenue received, and the export value of the cargo. The payment range is between 4% and 30% for container terminals.

Third, the contracts are of the brownfield type (72%), and only 28% are of the greenfield type projects. Among the Brownfield projects, the BROT type contract is the most predominant in the region. Fourth, the average concession terms are between 15 and 30 years, except for some exceptional cases (such as the Port of Santos in Brazil with a term of 50 years and SPR Cartagena and SPR Barranquilla ports in Colombia with 40 years). Concessions are predominantly for a fixed term. However, some contracts establish the possibility of extending the concession period. Fifth, contracts generally include mandatory and based on-demand investments. Mandatory investments aim to ensure compliance with specific requirements, such as minimum levels of productivity, maintenance, and services. Based on-demand investments are activated by triggers.

Zhang (2005) argues that the critical factors for success in PPPs agreements in ports are having economic viability and an auspicious investment environment, a reliable concessionaire with strong technical power, a solid financial package, and an adequate allocation of risks through reliable contractual arrangements. However, the socioeconomic situation is an obstacle to the reform of port infrastructure in Latin American countries. Port projects with a higher level of risk are shelved and abandoned. This abandonment has a negative impact on economic development both in the areas near the port and in the country where they are located. Therefore, it is evident that port infrastructure development happens in well-developed institutional capacities, price competition, regulatory policy, and investment plans (Wilmsmeier and Monios, 2016).

In most port PPPs, the private sector assumes the risks of operation, design, and construction. In contrast, the public sector assumes the risks of land management, political, regulatory, and force majeure. Users must assume the inflation and exchange rate risks, which are transferred to the tariff. In some countries, both government and companies share some risks. For instance, minimum requirements for operation, quality, and minimum service standards are established (Suárez-Alemán et al., 2020).

The main risk, demand risk, is assumed in almost all cases by the private sector. In Latin American countries, few exceptions are observed. Therefore, the risk-sharing mechanisms observed in the region frequently only allow the implementation of port projects with a high profitability level. Port development is only carried out when it responds to private interests (ports for private use), generating opportunism for the private sector. A clear example is the port concessions initiated by private firms, which exclude its use by other interested parties. To avoid this problem, greater government participation is required through support mechanisms primarily to mitigate revenue risks.

Although Latin America concentrates the majority of PPPs agreements than other regions of the world, there are still many needs and challenges in the sector. It is still necessary to increase the competitiveness of the ports in the region and the capacity of the facilities and cover the deficits in operating capacity (Wilmsmeier and Monios, 2016).

Another key infrastructure of transportation networks is Airports. In the countries of the LAC region, approximately 168 airports have been developed using the PPPs scheme. By 2020, investments in the airport sector through PPPs totaled more than 38 billion dollars. The use of PPPs to develop airports is widespread in the region. Public-private partnership agreements have complemented public-sector financing and improved the efficiency, competitiveness, and quality of airport services (Alemán et al., 2020).

According to the IDB (Inter-American Development Bank), by 2020, airports operating under PPPs agreements handled over 75% of the total passenger traffic in the LAC (Latin America and the Caribbean) region. In Brazil, this percentage is 66%. Figure 4.2 illustrates the participation of airports operated under PPPs in the countries of Latin America and the Caribbean. Airports not operated under PPPs are managed mainly by state entities. Brazil previously had the majority of airports operated by state entities. However, by the end of 2023, the country had concessioned more airports, primarily smaller ones.

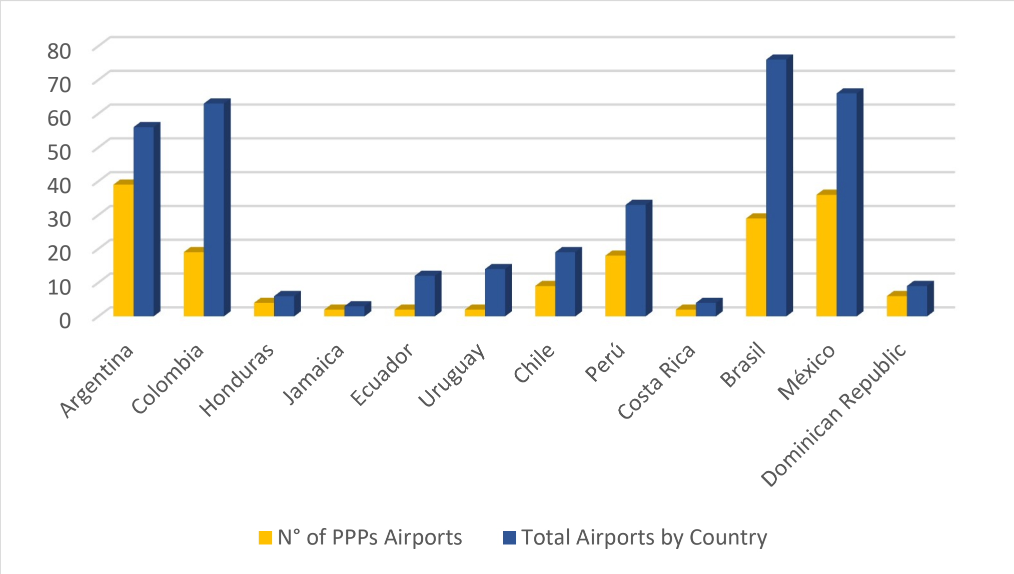

Figure 4.2 – Number of airports operated through PPPs in Latin America and the Caribbean
Source: BID-Inter-American Development Bank (2020)

The vast majority of airports in the region, especially the large ones with over one million passengers, manage to generate profitability for the concessionaire and compensate the governments. The operators of these airports are responsible for the operation of the terminal and air activities. Therefore, they receive compensation for airport activities carried out (tariffs) and commercial activities. Table 4.1 displays the variable compensation to the government in various airports in the region.

Table 4.1 – Variable remuneration at airports in the region

Airport of	Country	Variable Payment
Guarulhos	Brazil	10% of income
Viracopos	Brazil	5% of income
Brasilia	Brazil	5% of income
Belo Horizonte	Brazil	5% of income
Barranquilla	Colombia	14.6% of income
Cali	Colombia	41% of income
Quito	Ecuador	2.5% - 4.5% of EBITDA
Palmerola	Honduras	10% of income
Lima	Perú	47.5% of income
Santiago de Chile	Chile	77.5% of income

Airports with fewer than one million passengers face economic and financial challenges. In an attempt to make them sustainable, the vast majority of these types of airports are auctioned off in blocks. In block concessions, it is common to group a larger airport with over one million passengers along with several smaller airports. This practice aims to cross-subsidize the operation of the smaller airports. For example, in Mexico, as part of the Grupo Del Pacifico, there are airports like Manzanillo and Morelia. As part of the Grupo Nororiente, there are airports like Valledupar and Riohacha in Colombia. In Brazil, the practice of bidding in blocks began in 2019 and was utilized in the 5th, 6th, and 7th rounds of concessions (See Chapter 3, Section 2.3).

Most airport contracts in the region have a fixed term, with an average minimum duration of 20 years. Chile is the only exception. In the Santiago de Chile airport, the first concession contract ended when the concessionaire reached a certain level of revenue. It is also a tendency for PPPs to be carried out in airports with partially or fully existing infrastructure. In the region, it is common for the bidding process to attract five or fewer competing companies. This results from the high degree of concentration in the airport industry in LAC. The most used auction criterion is the highest grant value paid to the government. Table 4.2 presents the auction criteria used in the LAC region. These criteria can be used individually or in combination, so the total may not necessarily sum up to 100%.

Table 4.2 – Main auction criteria used in the LAC region

Auction Criteria Type	Countries	Percentage
Higher grant value, paid to the government.	Brazil, Colombia, Mexico, Chile, Argentina, Costa Rica, Ecuador, Honduras, Perú.	48%
Lower subsidies, paid by governments.	Brazil, Chile, Perú.	13%
Lowest tariff charged to users.	Chile, Colombia.	22%
Lower revenue paid to the operator.	Chile	11%
Shorter contract duration.	Chile	15%
Higher Investments.	Brazil	7%

In the 1990s, many countries in the region did not have a solid and specific regulatory and institutional framework to implement Public-Private Partnership (PPPs) agreements in the airport sector. Consequently, almost 45% of the PPPs signed during these years had to undergo renegotiation processes. These renegotiations had different origins, but the main ones were of a political and economic nature due to weak regulation and law gaps (Alemán et al., 2020).

Over the years, all airport contracts have undergone some form of renegotiation. The main areas of renegotiation are related to investment, payments to the government, and tariffs. Among the factors affecting the performance of airport PPPs in the region are cost overruns, delays, and demand. Contracts have a high tendency to present excess costs. Regarding the development of works, airports have experienced average delays of 25 months. Furthermore, the demand realized was lower than the projected demand in most cases.

Finally, investment in parks and natural preservation areas has been gaining significant interest from private investors and governments in Latin America and the Caribbean (LAC). Although parks are not infrastructure projects per se, they are extremely important due to the several benefits they can generate for society. Some of the main benefits include their social potential (health benefits, entertainment, community cohesion), environmental potential (impact on climate change mitigation, resilience, conservation, and protection of biomass and ecosystems), and economic potential (eco-tourist attractions, contribution to the appreciation of adjacent areas, and others) (Lembo et al., 2023).

Table 4.3 – Status of the Legal framework for PPPs in parks in LAC

Legal Framework for the PPP in Parks: In the process of developing	**Legal Framework for PPPs in Parks: Moderately Advanced.**	**Legal framework for PPPs in Parks: Advanced.**
Trinidad and Tobago	Costa Rica	Dominican Republic.
Jamaica	Bahamas	Guatemala
Surinam	Salvador	Chile
Haiti	Guyana	Brazil.
Panama	Honduras	Colombia
Belize	Nicaragua	
Barbados	Paraguay	
Argentina	Peru	
Bolivia	Mexico	
Ecuador	Uruguay	
	Venezuela	

Source: Lembo et al., (2023)

In Latin America and the Caribbean, few countries have specific applicable regulations for developing parks through PPPs. The vast majority of countries do not have specific regulations. Table 4.3 shows the status of the legal framework of the LAC countries. Only five countries have a well-developed legal framework to implement PPPs projects in parks. These countries have both general and specific regulations applicable to PPPs in parks.

Table 4.4 shows how park projects are developed in the five countries with advanced legal frameworks. Chile, Brazil, Colombia, and the Dominican Republic allow the development of investment projects through private initiatives. Guatemala is the only country that does not allow the submission of private initiatives. Another critical factor is the portfolio of parks. Only Guatemala, Brazil, and Colombia have a portfolio of parks to select those with greater interest or importance.

Regarding the 11 countries with a moderately advanced legal framework, all except Venezuela have general regulations applicable to PPPs in parks. However, none of them have specific regulations. Similarly, all of them, except Venezuela, allow the development of parks through private initiatives. None of the 11 countries have a portfolio of parks.

Regarding the countries with a developing legal framework, only Haiti, Barbados, Belize, and Suriname have regulations on Public-Private Partnerships (PPPs). However, these regulations do not apply to parks.

Table 4. 4 – Characteristics of countries with an advanced legal framework

Country	Development by Private Initiative	Portfolio in Parks
Dominican Republic.	Yes	Not
Guatemala	Not	Yes
Chile	Yes	Not
Brazil	Yes	Yes
Colombia	Yes	Yes

Source: Lembo et al., (2023)

4.2.
Public-Private Partnerships: Problems and Challenges

Despite the evident importance of investing in infrastructure, there is still a need for more investment. In the region, there have been significant advances, but in several countries, basic infrastructure is far from adequate, especially in the poorer countries. According to Cuesta et al. (2023), 20% of people with low incomes and greater vulnerability in Latin America and the Caribbean (LAC) live in peripheral areas with greater infrastructure deficits. In other words, the region still faces significant challenges in ensuring access to basic infrastructure services. One of the most limited infrastructures in LAC is interurban transportation.

On the one hand, deficiencies in terms of lack of adequate infrastructure are a problem. On the other hand, PPP projects in operation also face several challenges that hinder the proper delivery of services.

One of the challenges related to the operation of PPPs in Latin America and the Caribbean is to carry out adequate control. PPPs enhance the quality of public services, increase efficiency and transparency, and help solve bureaucratic problems. However, for these benefits to materialize, effective oversight along with a sound institutional framework is necessary.

In the LAC region, corruption is one of the most common perverse practices in bidding and any public contracting processes. Corrupt practices often occur in the proposal review processes, with unjustified increases in budgets, overpricing, and resulting in low project quality. An efficient control system can help address corruption issues. However, if not done correctly, it can have adverse effects. Excessive control, instead of solving problems, can become a barrier to investment, generate unnecessary delays, and limit innovation. Furthermore, excessive control that leads to ex-post changes (mainly changes to contracts) can lead to legal processes and, in the long term, more significant costs for society. Therefore, to access the benefits of PPPs, countries in the region must have efficient control bodies (Brito Cardoso et al., 2021).

Another challenge faced by PPPs is the management of contingent liabilities. One of the characteristics of PPPs is that they allow some risks, or a portion of them, to be transferred to the private partner. Risks that governments are unable to transfer constitute the sources of contingent liabilities. Non-transferred risks, if materialized, can lead to increases in the public budget. The effects of contingent liabilities are evident in cost increases or revenue declines, which impact project returns, especially in a PPP contract.

Contingent liabilities are uncertain, therefore, it is necessary to carry out a valuation and design appropriate management of PPP project commitments. This controls potential long-term impacts and ensures that governments can pay and meet commitments if necessary.

According to Prats Cabrera et al. (2023), valuation involves two different approaches. First, the maximum exposure is related to the total value involved in the guarantee. Maximum exposure reflects the worst-case scenario, which usually has a low probability of occurring. Second, the expected value considers the probabilities of events triggering the liability payment. Therefore, for proper valuation of liabilities, it is necessary to estimate the expected value of payments, calculate the variability of payments, and calculate the present value of payments.

Contingent liabilities and fiscal impacts of PPPs are not controlled by traditional mechanisms (Reyes-Tagle et al., 2021). Therefore, countries in Latin America and the Caribbean are implementing different measures to try to control them. In general, the study of contingent liabilities and the need to assess them began with the study of the impacts of revenue or demand guarantees. Currently, countries use very similar valuation methodologies. However, Chile strongly emphasizes calculating liabilities related to minimum revenue guarantees and exchange rate fluctuations. In Peru, the government does not provide exchange rate protection but instead examines liabilities derived from potential cost overruns and renegotiations. Colombia is the country that is most concerned with monitoring and tracking contingent liabilities (Prats Cabrera et al., 2023).

4.3.
Capital Investment in Stages

Many factors influence the decision of capital investors. Revenue uncertainty is one of the main risks that can have a negative impact. Revenue risk is essentially important since revenue is necessary to cover operational costs, repay debt financing, and provide profits. Revenue uncertainty is directly related to demand. Demand uncertainty is a function of multiple interrelated uncertainties that vary over time, so a change in one can affect the others (Taneja et al., 2010b).

Although these risks and uncertainties are generally considered undesirable project characteristics, they can be transformed into opportunities through the incorporation of flexibility. This allows decision-makers to adapt the project to changes in the economic environment, dynamically adjusting their operational strategy (Herder et al., 2011).

The port infrastructure sector rarely includes revenue or demand guarantee clauses in contracts. According to (Gómez-Fuster; Jiménez, 2020), risk analysis is not common in port infrastructure projects. Generally, in this sector, demand risk is assumed by the private sector. The preferred form of demand risk mitigation is expanding the port based on future demand.

Table 4.5 shows three ports in Peru that use a phased expansion approach to mitigate demand risk. According to Table 4.5, it can be inferred that the use of triggers to initiate the construction of a new phase is frequent. This feature is very common in ports concessioned by the private sector. However, when a trigger is activated, the construction of the new phase is mandatory. This mechanism only applies within the first 20 years of the concession.

4.4. Demand Triggers Expansion

Table 4.5 presents a different alternative for dealing with demand uncertainty. Among the three cases, the one that stands out most is the Salaverry Multipurpose Port Terminal. In 2018, the government of Peru granted the Port of Salaverry in concession to the Consorcio Transportadora Salaverry. The modality of the concession contract was the self-financed Public Private Association, which includes the modernization, reinstatement, crane installation, and operation of the terminal for a period of 30 years.

The port of Salaverry is located in the department of La Libertad. Until the concession date, the port was administered by the Peruvian State under the Landlord Port model. In July 2017, the declaration of interest for the Self-financed Private Initiative project, Modernization, and development of the Salaverry Multipurpose Port Terminal, was approved. The Consorcio Transportadora Salaverry won by offering the highest discount on the cargo movement tariff (discount value of 10%).

The concession of the Salaverry Terminal included a total investment amount of US$ 228,9 million and the construction of five expansion stages. Figure 4.3 shows the Port of Salaverry and the location of the expansion stages and the new dock. The construction of stages 1 and 2 are mandatory and were to be carried out within the first five years of the concession. Investment in stages 3, 4, 5, and the new dock were conditional on the demand reaching a pre-established level. Table 4.5 shows the investment values of each phase, as well as the triggers that activate the construction of each phase.

Table 4.5 – Investment on-demand in port PPPs contracts

	Terminal Portuario General San Martín - Pisco	**Terminal Norte Multiproposito en El Terminal Portuario Del Callao**	**Terminal Portuario Multipropósito de Salaverry**
Type of port	Container terminal Type: DBFOT(Design, Build, Finance, Operate and Transfer)	Container terminal Type: DBFOT(Design, Build, Finance, Operate and Transfer)	Container terminal Type: DBFOT(Design, Build, Finance, Operate and Transfer)
Concession period	For 30 years.	For 30 years.	For 30 years.
Concession Year	2014	2011	2018
Grant criteria	Tariff: winning the proposal with the highest tariff discount. Additional investment: winning the proposal with the highest additional investment.	Tariff and highest tariff discount.	Highest tariff discount
Total investment	Total investments of US$ 131,119 million: Inversion of Stage 1 of US$ 53.051. Investment of Stage 2 of US$ 28,858. Investment of Stage 3 of US$ 37,877. Investment of Stage4 of US$ 11,332 million	Total investments of US$ 748 713 million: Inversion of Stage 1: US$ 206 2039. Investment of Stage 2: US$ 100929. Investment of Stage 3: US$ 120 677. Investment of Stage 4: US$ 154 396 million Investment of Stage 5: US$ 166 470 million	Total investments of US$ 228 971 million: Inversion of Stage 1 and 2: US$ 102 154. Investment of Stage 3: US$ 19 1389. Investment of Stage 4: US$ 17 481. Investment of Stage 5: US$ 29 247 million. Investment in new dock: US$ 60 948 million.
Investment based on demand	**Stage 2:** Required when in one year, within the first 20 years, a total demand of 2500,000 MT / year is reached. **Stage 3**: Required when in one year, within the first 20 years of concession, a total demand of 60,000 TEU per year is reached. Only enforceable after finishing stage 2. **Stage 4:** Required when in one year, within the first 20 years of concession, a total demand of 225,000 MT / year of clean grains (edible grains) is reached.	**Stage 3:** Required when in one year, within the first 20 years, a total demand of 1.00 million TEU per year is reached. **Stage 4**: Required when in one year, within the first 20 years of concession, a total demand of 1.3 million TEU per year is reached. **Stage 5**: Required when in one year, within the first 20 years of the concession, a total demand of 1.5 TEU per year is reached.	**Stage 3:** Required when in two consecutive 12-month periods, within the first 20 years, the movement of clean bulk (wheat, corn, and others) reaches 1.2 million tons each year. **Stage 4**: Required when in two consecutive 12-month periods, within the first 20 years, the movement of mineral concentrate reaches 800,000 tons, or the movement of fertilizer and/or soy reaches 1,800,000 tons. **Stage 5**: Required when in two consecutive 12-month periods, within the first 20 years, the movement of mineral concentrate reaches 1.2 million tons each year.

			New dock: Required when, within the first 20 years, the movement of mineral concentrate reaches 1,800,000 tons, or the movement of fertilizer and / or soy reaches 1,800,000 tons.
Trigger type	Stages 2 and 3 are sequential. Stage 4 is independent.	The execution of each stage is sequential (to start a stage, it is necessary to have finished the previous stage).	The execution of each stage is independent.

The case of the Terminal Portuário de Salaverry presents several innovations that can be adapted to other sectors. First, the contract distributes the total investment across multiple phases instead of just including a demand guarantee. The start of each phase depends on reaching a certain level of demand. In other words, construction is only carried out if there is sufficient demand to trigger the start of investments.

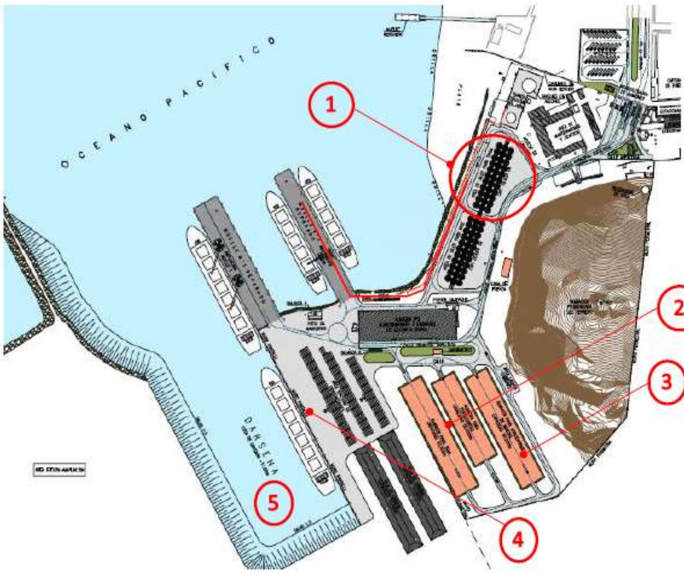

Figure 4.3 – Port of Salaverry, Layout of the stages, and the new dock
Source: Cassinelli (2018).

Second, unlike a normal infrastructure where construction is sequential, in this case, the construction is independent. In other words, the construction of one phase does not depend on the construction of previous phases. Consequently, one section of the port can be much more developed than another. Third, the triggers that activate investments do not represent a single level of demand. In this contract, in addition to reaching the trigger, the contract establishes that the demand must be equal to or greater than this demand level for various consecutive periods. In other words, it is not just about reaching the trigger. Essentially, it is about reaching and maintaining it for 24 consecutive periods (months). If, during these 24 months, the demand falls below the trigger, the investment is not activated, even if it's for a single month. Fourth, when the trigger is reached and meets the 24-month requirement, demand-driven investment becomes mandatory. Once activated, the concessionaire must obligatorily carry out the investment and construction.

This strategy can be applied to other sectors that allow independent construction, in which an area does not depend on the construction of previous areas. For example, sports centers, hospitals, schools, social housing buildings and airports.

In Brazil, this strategy has already begun to be implemented in the 6th (2021) and 7th (2022) rounds of airport concessions (see Chapter 3, Section 3.3.2 - Table 3.4). In these recent rounds, contracts included three investment triggers. Each trigger initiates new investments in facilities, terminals, aircraft yards, track systems, and others. However, only one trigger is defined in the contract. The other triggers are not specified.

5
Mitigation of Demand Risk through the Implementation of a Demand Coverage Model

Currently, much attention is given to the allocation and sharing of risk. Concession contracts include clauses for sharing; mainly, demand and exchange rate risk (see Tables 3.1 and 3.2). The sharing of risks among partners means that the Grating Authority assumes part of the risks. The value for the Granting Authority is that the project must generate greater benefits for society compared to the cost of sharing the risk.

The modeling of concession contracts has evolved over the years. Since the first stages of concessions (1994 for federal highways and 2011 for airports), at each stage, new modifications or innovations were included in the contractual modeling. An interesting innovation is the implementation of a bank account mechanism. The state of São Paulo was one of the first to incorporate this innovation, including it in the concession contracts for the Lote Centro-Oeste Paulista and Lote Rodovias dos Calçados. Initially, the accounts mechanism was designed to compensate for the results of the exchange rate risk mitigation mechanism. Currently, the mechanism aims to ensure the economic-financial sustainability of the concession.

Most academic studies on risk-sharing mechanisms in concessions and PPPs are focused on calculating their value and effect (see Chapter 2, figure 2.6). Although these studies make important contributions, they do not analyze the applicability in situations of disruptive events. Furthermore, there is little attention to how to fund the results of risk-sharing mechanisms. That is, how to cover the liabilities generated by the sharing mechanism, without placing a burden on the granting authority.

Therefore, this chapter aims to propose a new strategy to mitigate demand risk through risk sharing, but without generating liabilities for the granting authority. This model combines the Minimum Revenue Guarantee (MRG) with the Accounts Mechanism. The MRG is used to mitigate demand risk, and the Account

Mechanism is used to generate funds to compensate the MRG. To illustrate the functioning of the model, we use the International Airport of Rio de Janeiro-Galeão as a case study.

This chapter is organized as follows. Section 1 describes demand risk in infrastructure projects. Section 2 provides a detailed explanation of how the accounting mechanism works. Section 3 presents the proposed model. Section 4 presents the results of a case study that applied the model. Section 5 describes the model using real options. Section 6 refers to a sensitivity analysis of the model parameters. Finally, in Section 7, we discuss the results

5.1.
Risk Management in Infrastructure Projects.

Infrastructure projects are developed using several mechanisms. The most common mechanisms, involving private participation, are the common concession, sponsored concession, and administrative concession. These modalities differ depending on the concessionaire's form of remuneration. Table 5.1 details the different forms of remuneration. Sponsored concession and Administrative concession are known as PPPs.

Table 5.1 – Concession Modalities

Modality	Concessionaire Compensation
Common Concession	- Arise exclusively from the payment of tariff charged to the user. - Does not involve Government participation.
Administrative Concession	- Remuneration paid (100%) exclusively by the Granting Authority.
Sponsored Concession	- Tariff paid by the user + additional amount paid by the granting authority. -This involves sponsorship by the granting authority.

In Brazil, most state-initiated projects (such as metro, VLT, and subways) are developed using the sponsored concession modality, because they require sponsorship to be implemented. Federal highways are developed using the Common Concession modality. The remuneration in this case comes from the toll tariff. However, when projects are perceived as highly profitable, to grant the concession, an amount is expected to be paid by the concessionaire to the granting authority. This is the case with airports. In Brazil, all federal airports were concessioned charging a grant to the concessionaire.

Unfortunately, several risks and uncertainties affect the development of infrastructure projects. A literature review from 2000 to 2021 has shown that demand is the main source of uncertainty (See Table 2.1). Variations in demand directly impact the cash flow and project profit. Two factors constitute demand risk: First, risk of demand in standard situations. In this case, the variation depends on user preference. Second, the risk of demand due to disruptive events. The latter can be positive or negative. When they are negative, they can lead to economic losses. Disruptive events are very frequent, but sometimes they go unnoticed because they are not extreme or their effects are transitory (Alessio Stanganello et al., 2023).

COVID-19 has been one of the most important negative disruptive events in recent years. In the field of infrastructure projects, COVID-19 compromised the cash flow generation of projects, in some cases transforming a profitable project into a deficit. Figure 5.1 displays the passenger demand series for eight of the European Union's main Airports from 2012 to 2022. This figure shows that before the pandemic (COVID-2019) airports had an almost standard variation in demand, with periods of repetitive demand fluctuations (high-low) and accompanied by a growth trend. However, at the beginning of 2020 (pandemic), demand dropped abruptly. This drop was extreme, but not permanent. In the last quarter of 2021, demand at several airports began to increase and return to its initial levels.

The perception of demand risk negatively impacts the interest of private investors. When the risk is perceived as excessive, concession contracts include risk-sharing clauses to attract private participation. It is expected that by sharing the risk, a better bidding proposal will be made possible, with better results. Unfortunately, in practice, this does not always happen. An excessive drop in demand or incorrect distribution of risks can generate excessive liabilities for the granting authority, leading to a greater budgetary burden. Subsequently, the granting authority faces a commitment to compensate the concessionaire. Non-compliance also discourages private interest.

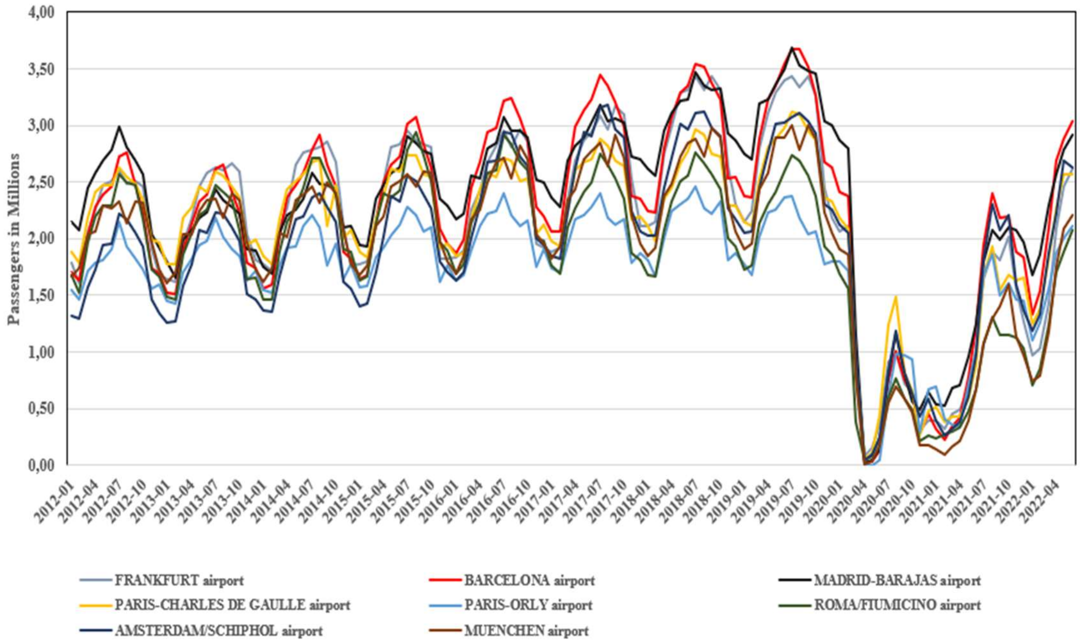

Figure 5.1 – Air passenger transport between main airports in European Union

5.2.
Accounts Mechanism in Concessions Contracts

The accounts mechanism aims to ensure the health and economic-financial sustainability of the Concession (ANTT, 2023). This mechanism involves a set of accounts linked to the concession, which are only used to receive deposits authorized in the contract. They are accounts owned by the concessionaire, opened in the Depositary Bank, and operated exclusively as the contract indicates.

In highway concessions, the accounts mechanism has already been included in several concession contracts. However, its operation became more defined in the last concessions. For example: BR-153/TO/GO, BR-080/GO, BR-414/GO (Ecovias do Araguaia); BR-116/465/493/RJ/MG (EcoRioMinas), and CCR Rio/SP (Rio de Janeiro – São Paulo Road System).

The main accounts of the mechanism are:

- Centralizing Account: where the Gross Revenue of the Concession is deposited. It is used to transfer funds between the Concession Accounts (Adjustment Account and Retention Account) and the Free Movement Account. The movement of its funds is restricted;
- Adjustment Account: where the funds generated by the concession are deposited. These funds are used for economic-financial rebalancing, final

Results Adjustment, and Frequent Users discount. The movement of these resources is restricted and depends on the ANTT authorization;

- Retention Account: Where portions of the funds remained deposited, intended exclusively for application and compensation of the Exchange Protection Mechanism;
- Free Movement Account: Account with free movement by the concessionaire. Here the balance of the Centralizing Account is deposited, after transferring funds to other accounts;
- Contribution Account: where amounts related to the Grant Value are deposited. The amounts deposited depend on the terms and clauses of the concession contract. Its movement is exclusively carried out by ANTT.

Depending on the characteristics of the concession, contracts may include other types of additional accounts. For example: The Free Flow Account (EcoRioMinas Concessionaire), the Trecho Viúva Graça Account (CCR Rio-SP Concessionaire).

Figure 5.2 shows the methodology of the account mechanism and its operation. First, all gross revenue from the concession is deposited in the Centralized Account. Second, a portion of resources is transferred to pay the Inspection Fund (Single Treasury Account). Third, a portion of the resources is transferred to the Adjustment Account and Retention Account. Fourth, the remaining balance is transferred to the Free Movement Account (ANTT, 2023).

Fifth, after retention indicated in the contract, if there are surpluses in the Retention Account, these resources must be transferred to the Adjustment Account. Sixth, in case of exchange compensation to the concessionaire, the resources to be compensated are transferred from the Retention Account to the Free Movement Account. Seventh, in case of payment to the concessionaire due to the Frequent User Discount, rebalancing notification, or Final Adjustment, the amounts are transferred from the Adjustment Account to the Free Movement Account. Finally, at the end of the Concession, in case of balance in the accounts, all the resources are transferred to the Free Circulation Account.

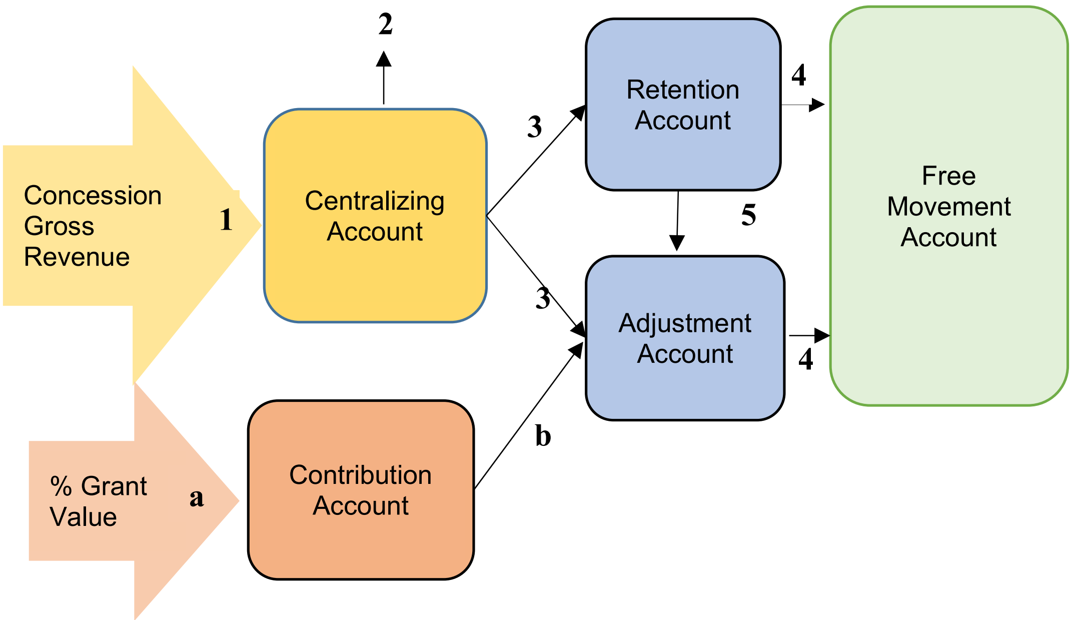

Figure 5.2 – Methodology of the operation of the Accounts Mechanism

The Grant Value is also included in the mechanism: a) a percentage of the Grant is deposited into the Contribution Account. (b) The resources in the Contribution Account are transferred to the Adjustment Account.

The contract with Concessionaria Ecovias Do Araguaia depicts the use of the Grant Value. In addition to the Exchange Protection Mechanism, this contract includes the Tariff Revenue Risk Mitigation Mechanism (ANTT, 2023). As a result of the Mitigation Mechanism, any compensation by ANTT to the Concessionaire is made with the financial balance available in the Adjustment Account. According to the contract, the Adjustment Account comprises: i) resources from the Contribution Account and ii) 7% of the Gross Revenue from the 1st to 10th year of concession. Thus, the Ecovias Do Araguaia mechanism evidence using the Grant Value to compensate for the Tariff Revenue Risk Mitigation Mechanism.

In summary, the accounts mechanism aims to ensure that the concession will have the financial resources (originating from the concession itself) necessary to fulfill the signed commitments. In addition to ensuring the payment of possible future liabilities, it is also beneficial for the parties involved in the contract. On the one hand, there is greater certainty that the protection or mitigation mechanisms will be compensated. On the other hand, the Granting Authority does not increase its budgetary burden if it is necessary to compensate the Concessionaire.

This is of interest to investors because it represents a project hedge capable of encouraging private participation. Although the accounts system is a great innovation, it also requires correct supervision and control of the use of accounts, to reduce possible opportunistic behavior. Therefore, several experts emphasize the importance of strengthening regulatory agencies.

5.3.
The Model

The concession contracts have adopted mechanisms to mitigate the risk of demand and the risk of revenue fall. However, in cases of extreme fluctuation and demand drops, these mechanisms can generate high liabilities for the government besides being insufficient to fulfill their function. In the literature, it is possible to identify two fundamental problems. First, few researchers address the issue of how to obtain the necessary resources to compensate the concessionaire in cases of a drop in demand. The granting authority compensates the concessionaire using its resources, thereby increasing the budgetary burden. Second, few studies propose mechanisms to mitigate the negative effects of disruptive events.

To solve these issues, this chapter proposes a new mechanism to mitigate demand risk by combining the Minimum Revenue Guarantee (MRG) with the Account Mechanism. In the new proposed model, MRG is used to mitigate demand risk in both normal and extreme (disruptive) fluctuations. The Account Mechanism is employed to retain and deposit portions of the Grant Value, which will later be utilized to compensate the MRG. The purpose of retaining a portion of the Grant is to accumulate resources for self-financing the MRG and avoid the generation of contingent liabilities for the Granting Authority. This new model was named Minimum Revenue Guarantee with Guaranteed Liabilities Mechanism (MRG/GL).

The methodology of the MRG/GL mechanism is described below:

First, we build the Escrow Account (EA). The Escrow Account is a bank account with restricted transactions, where the money arising from the retention of installments of the grant value will be deposited. According to the following process:

A portion of the Total Grant Value that the concessionaire pays to the Granting Authority is retained and deposited in an Escrow Account. The value in EA for each retention period is:

$$GR = TGV * (\%r) \qquad (1)$$

The value accumulated in EA for each period, brought to Present Value is:

$$TGR_m = \sum_{t=1}^{m} \left(\frac{GR}{(1+r)^t} \right) \qquad (2)$$

Where:

TGV: is the Total Grant Value
$\%r$: is the percentage to retain
GR: Amount of Grant retained
r: is the discount rate
TGR_m: is the Total Grant retained, brought to Present Value.
m: is the retention period, and t: varies from 1 to m.

The TGR held in the Escrow Account is used to compensate the MRG.

As the grant value is a judgment criterion, its value cannot be determined in the pre-auction stage. Therefore, for the model, we have defined that the grant value is equal to the minimum grant value established in the concession notice. This choice brings two advantages. On the one hand, it allows for the modeling of a concession before the bidding process. On the other hand, the existence of a fixed value previously established in a notice prevents concessionaires from offering astronomical amounts. In this way, we seek to avoid opportunistic behavior, in an attempt to offer more grants to obtain greater compensation when exercising the demand guarantee.

Second, for revenue guarantee compensation, we set the revenue threshold. Several concession contracts that include revenue guarantees use demand bands as limits for risk sharing. We follow these models and propose a simple formula to set the lower revenue limit. Unlike a model with a demand band (floor and ceiling) that constitutes a collar, in this new model, we only define the lower demand limit (floor). Thus, for the entire period during which the revenue guarantee is in effect: Step 1: the Reference Revenue (r_f) is defined year by year. Step 2: for each year of validity of the demand guarantee, we discount the reference revenue for that year (R_{fn}) to present value using the formula:

$$R_{fn} = \frac{r_f}{(1+r)^n} \qquad (3)$$

Step 3: Based on the Present Value of the Reference Revenue, we set the lower reference limit:

$$RMin_n \quad = R_{fn} * (1 - a) \qquad (4)$$

Where:

a : Lower band amplitude, expressed in percentage
$RMin_n$: Minimum reference revenue limit (expressed in Present Value)
n : Operating period of the mechanism, n: 1, 2, ..., v. Where v is the end of the mechanism's validity.

Third, determining the values to be compensated. To calculate the amounts to be compensated, we bring the Realized Gross Tariff Revenue (RTR) to the Present Value (PV). We use equation (5):

$$RTR_n = \frac{Realized\ Gross\ Tariff\ Revenue_{\ n}}{(1+r)^n} \qquad (5)$$

Fourth, if the PV of the Realized Gross Tariff Revenue (RTR_n) is lower than the Minimum Revenue limit($RMin_n$), the granting authority must compensate (C_{1n}) to the Concessionaire using the funds available in the Escrow Account (EA). The compensation C_{1n} is carried out up to a maximum limit equivalent to the balance available in the Escrow Account. The following equation illustrates the process:

$$If: \quad RTR_n > RMin_n \text{ So: } C_{1n} = 0$$

or

$$If: \quad RTR_n < RMin_n \text{ So:}$$

$$C_{1n} = \min(RMin_n - RTR_n; TGR_m) \qquad (6)$$

Fifth, in each period of operation of the new mechanism (MRG/GL), the balance in the Escrow Account (BEA_n) is determined as:

$$BEA_n = TGR_m - C_{1n} \qquad (7)$$

After the compensation, the BEA_n must be transferred to the granting authority. Since the funds in the EA constitute portions of the Grant Value. Finally, the new mechanism (MRG/GL) generates the following results.:

i. When there is a drop in demand and whenever it is below $RMin_n$: The concessionaire is compensated for the demand risk, up to the maximum balance available in the Escrow Account (EA).

ii. When demand is higher than $RMin_n$: there is no compensation in favor of the concessionaire. The TGR_m value in the EA is transferred to the granting authority, after the previously established minimum period of stay.

The mechanisms for mitigating demand risk act as guarantees for the concessionaire. These mechanisms alter the project risk, therefore, the value of the impact of guarantees cannot be calculated using the DCF method. The best methodology to calculate this value is the Real Options approach. Since, when a guarantee is included, the project risk changes, and therefore the discount rate relates to this new risk (Brandão et al., 2012). Furthermore, according to the literature, MRG mechanisms have characteristics of options because they represent rights, not obligations. Depending on the exercise date, they can be modeled as American-type or European-type options. Therefore, to calculate the value of the new mechanism proposed in this chapter (MRG/GL), we use the Real Options approach.

5.4.
Application

To exemplify the functioning of the new MRG/GL mechanism, we modeled an infrastructure project based on a real case. We chose the concession of the International Airport of Rio de Janeiro – Tom Jobim/Galeão as a real base case. Two factors motivate this choice: (i) it is a concession affected by demand risk and disruptive events (COVID-19); (ii) it is a project with the highest grant value (auction criteria) and the contract does not include any type of guarantee.

5.4.1.
International Airport of Rio de Janeiro – Tom Jobim/Galeão

The International Airport of Rio de Janeiro, also known as Galeão Airport was officially inaugurated in 1977. Located in the north of Rio de Janeiro, 13 km from the city center, specifically on Ilha do Governador (ANAC, 2013a). Galeão Airport is one of the most important airports in the country and occupies a total of 1,700 hectares. It can receive large aircraft and has one of the largest runways in Brazil. To improve service to air transport users, renew infrastructure, and attract investment, the Federal Government of Brazil decided to grant the Airport to the private sector. At the end of 2013, the auction was held as part of the second round of airport concessions. The winner of the auction was the Concessionária Aeroporto Rio de Janeiro S/A. Concessionaire formed by the Consorcio Aeroportos Do Futuro (Odebrecht Trans Port and Changi Airports International) with 51% and INFRAERO - Brazilian Airport Infrastructure Company with 49%. The consortium won the auction with a bid of R$19 million, a value 400% higher than the minimum bid of R$4.8 million (ANAC, 2014). The airport was concessioned for 25 years, with the possibility of extending the term for up to 5 years, exclusively to restore the economic-financial equilibrium (ANAC, 2013b). In April 2014, the concession contract was signed.

5.4.2. Current Situation of the Airport

At the time of the Airport concession, the Brazilian economy was experiencing strong growth, despite problems and crises on the international scene. Confidence in the economy was accompanied by positive prospects for growth in the country's productivity and economic activity. The airport sector also recorded significant growth. In 2012, around 17 million passengers passed through the International Airport of Rio de Janeiro. Figure 5.3 presents the passenger history at the Airport. The figure shows that from 1990 to 2004 demand remained constant, with an average of 5.9 million passengers per year. However, from 2005 to 2012, total passengers at the airport grew rapidly, at an average annual rate of 10.57%.

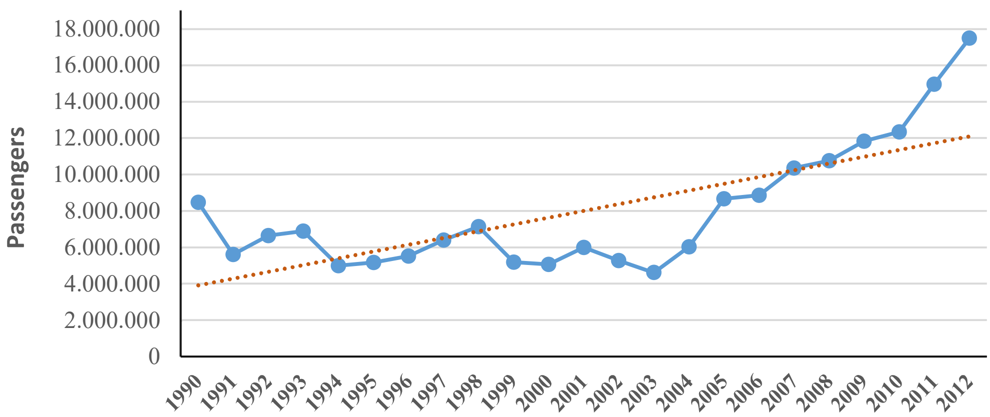

Figure 5.3 – History and evolution of passengers at Galeão Airport (1990- 2012)
Source: ANAC (2013c)

In 2013, for the bidding and concession process, the company Leigh Fischer was hired to carry out feasibility studies for the Airport (Technical, Economic and Environmental Feasibility Studies – EVTEA). According to Leigh Fischer, passenger demand in Rio de Janeiro was projected to increase from 26.5 million in 2012 to 84.1 million in 2043, growing at an average rate of 3.8% per year. For Galeão International Airport was projected that the demand would grow at a Compound Annual Growth Rate (CAGR) of 4.7% for total passenger traffic. Growth at a CAGR of 4% for Aircraft Movement and a CAGR of 3.7% for Air Cargo Movement (ANAC, 2013c). Table 5.2 presents the projection of total passenger growth.

Table 5.2 – Projected passenger demand by Leigh Fischer

Year	Forecast Passengers (in millions)
2013	19,269
2014	22,518
2015	23,149
2016	25,739
2017	26,728
2018	28,278
2023	34,538
2028	41,574
2033	50,138
2038	60,366

A constant and growing trend is observed in the demand projections. Some of the guiding assumptions for the projections, provided by the National Treasury, were:

- The Brazilian GDP would grow at a rate of 3.6% per year.
- The airport would maintain its leadership as the main airport in the region.
- The airport, in the role of a domestic and international hub.
- No other competing transportation modes would affect the airport's passenger demand during the period.
- No major disruptions or disturbances to travel behavior and airline services would exist.
- Slow growth in passenger demand at Santos Dumont Airport, due to facility restrictions.

- Positive impact of the FIFA World Cup 2014 and the Olympic Games in 2016.

However, the demand realized was completely different and distant from the initially projected demand. Figure 5.4 shows the projected demand vs the realized demand. The projection predicted that demand would grow steadily, however, from 2012 to 2019 demand gradually decreased. In 2020, the demand reduction was drastic.

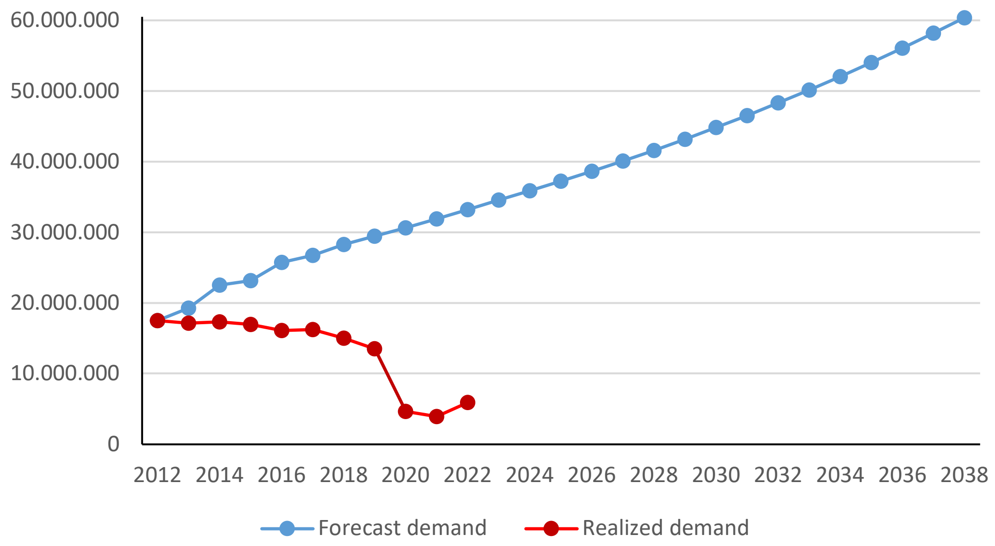

Figure 5.4 – Projected versus realized passenger demand at the International Airport of Rio de Janeiro (Galeão)

The COVID-19 pandemic has generated significant problems for the economy. The International Airport of Rio de Janeiro (Galeão), as well as other airports around the world, experienced a dramatic drop in demand. Figure 5.5 displays the passenger series at Galeão from 1990 to 2022.

According to experts, several factors may have contributed to the drop in demand at the Airport. First, the airport sector is highly sensitive to the economic situation. The drop in demand at Galeão is related to the situation in the State of Rio de Janeiro, which worsened with the pandemic. Second, Rio de Janeiro lost the protagonist it had compared to other regions in the country. This is especially true in terms of tourism owing to the lack of security in the State. Other factors include lack of access to the Airport and competition with other Airports. For domestic flights, competition with Santos Dumont Airport, and for international flights, competition with Guarulhos Airport.

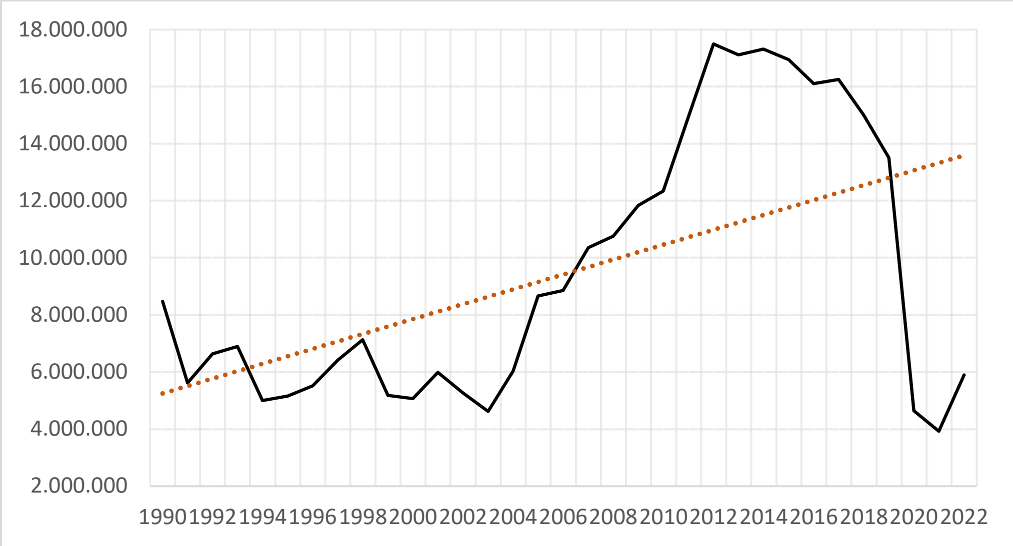

Figure 5.5 – History of passengers at Rio de Janeiro International Airport (1990-2022)

5.4.3. Real Base Case: Analysis of Bidding and Concession Documents

According to the modeling, the concessionaire receives remuneration due to the operation of the Airport. This remuneration is composed of tariff revenue and non-tariff revenue. Tariff revenues are charged to passengers and airlines operating at the Airport. Two categories of tariffs compose the tariff revenues: the airport tariffs and the tariffs for storage and cargo handling. The regulatory proposal developed for the Airport indicates the application of the IPCA-X-Q formula for airport tariffs. For storage and handling tariffs, only the IPCA is applied. The adjustment for annual airport tariffs is done using formula (8).

$$T_y = T_{y-1} * (1 + IPCA - X - Q) \tag{8}$$

where:
T_y: tariff for the year y.
T_{y-1}: tariff in the previous year
$IPCA$: percentage change in IPCA
X: efficiency adjustment
Q: service adjustment

Thus, airport tariff revenues are calculated using formula (9), and storage and handling tariff revenues with formula (10):

$$R_a = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7 \qquad (9)$$

$$R_{ac} = R_{im} + R_{ex} \qquad (10)$$

Where:

R_a: Airport tariff revenues
R_1: Domestic passenger boarding * domestic boarding tariff
R_2: International passenger boarding * international boarding tariff
R_3: International and domestic connecting passenger * connection tariff
R_4: Domestic landing MTOW * domestic landing tariff
R_5: International landing MTOW * international landing tariff
R_6: Domestic stay MTOW * domestic stay tariff
R_7: International stay MTOW * international stay tariff.

*MTOW: Maximum Take-Off Weight
R_{ac}: storage and handling tariff revenues
R_{im}: import tariff * processing of imported cargo (in tons)
R_{ex}: export tariff * processing of exported cargo (in tons)

To calculate the value of the project, Leigh Fischer projected the Cash Flow of the Galeão Airport Concession. The main assumptions included: project revenues (tariff and non-tariff), OPEX, Concession Fee Rebate, EBITDA, Depreciation, EBIT, Taxes, CAPEX, and Working Capital. In the modeling developed by Leigh Fischer, gross tariff and non-tariff revenues are penalized with deductions. OPEX comprises two categories i) related to personnel and, ii) not to personnel. Non-tariff Revenues and OPEX vary depending on demand. The Concession Fee represents the variable contribution (variable grant) depending on the annual gross revenues, which the concessionaire must pay. The PASEP/COFINS rebate is applied to 80% of the operating cost not related to personnel or total gross revenue, whichever is lower. As for Working Capital, Leigh Fischer estimated initial working capital for the first year and then annual changes in working capital. Table 5.3 shows the rates and assumptions used in Cash Flow modeling.

Table 5.3 – Parameters in modeling carried out by Leigh Fischer.

Premises	Value	Description
Factor X - in airport tariff	1,95%	Benefit of productivity gains (years 1-5)
Factor Q - in airport tariff	0%	Service quality factor
Taxes on Tariff Revenue	14,25%	Deductions relating to PASEP/COFINS and ISS
Taxes on Non-Tariff Revenue	10,15%	Deductions relating to PASEP/COFINS and ISS
Variable Contribution fee	5%	Variable contribution paid to the granting authority
Rebate taxes of PASEP/COFINS	9,25%	
Imcome Tax	34%	
Initial working capital	4,2%	Of revenue in the first year
Working capital needs	8,3%	of the variation in annual revenue
Concession Term	25	Years

To determine the value of the airport concession, Leigh Fischer calculated the Present Value (PV) of the concession. According to PV theory, the value of an asset today is equal to the cash flow it will produce in the future discounted at a rate that expresses its risk. To calculate the VP, Leigh Fischer assumed the annual discount rate (WACC) of 6.46%. Thus, the Net Present Value (NPV) of the Airport, at the time of bidding in 2013, was estimated to be R$ 1,501.5 million for a concession period of 25 years (ANAC, 2013d).

5.5. Modeling with Real Options: Value of the Mechanism

Unlike the Discounted Cash Flow analysis, the Real Options Approach allows for incorporating flexibilities and capturing the value of government support. To determine the value of the MRG/GL mechanism using the real options approach, we first modeled a base scenario without the inclusion of the MRG/GL mechanism. Since the objective is to show how the MRG/GL would have functioned if it had been included in the concession contract, we used the same modeling carried out by Leigh Fischer in 2013 as a reference point. This base scenario only differs slightly from that carried out by Leigh Fischer because some simplifications were included in the process of constructing the annual cash flows. However, the main criteria and parameters are maintained. We modeled the base scenario deterministically, at constant values from 2013, i.e., without including the IPCA.

Based on the projected demand by Leigh Fischer, presented in Table 5.2, we calculated Revenues. To calculate airport tariff gross revenues, we used equation (8) adjusted for each year, and equation (9). To calculate tariff revenue from storage and handling, we use equation (10).

To construct the Cash Flow for the base scenario, we used the same parameters presented in Table 5.2 and the following equation (11):

$$Cf_n = \left\{ \Big[[(Ra_n - D_1) + (Rac_n - D_1) + (Rnt_n - D_2)] - Opex - Tc + Ab \Big] - D \Big] (1 - i) \right\} + D - CAPEX - CGI - \Delta WCG \qquad (11)$$

Where:

CF_n: Cash Flow, in year n;
Ra_n: Gross Airport Tariff Revenue;
Rac_n: Gross Revenue from Storage and Handling;
D_1: Taxes on tariff Revenue;
Rnt_n : Non-Tariff Revenue;
D_2:Taxes on non-tariff revenue;
$Opex$: Operational expenditures;
Tc : Variable contribution fee;
Ab : Rebates;
D : Depreciation;
i : Income Tax;
$CAPEX$: Capital Expenditure;
CGI : Initial Working Capital;
ΔWCN : Change in Working Capital Need;
n : Year.

We calculated the project's cash flows for the 25 years of the concession. Appendix 4. Presents the cash flow of the base scenario. Subsequently, we determined the PV of the project using formula (12). This way, discounting the expected future Cash Flows to present value.

$$PV = \sum\nolimits_{t=1}^{n} \frac{Cf_t\,(.)}{(1 - wacc)^t} \qquad or \qquad \int_{t=1}^{n} E[Cf(.)]e^{-wac} \; dt \qquad (12)$$

Originally in 2013, Leigh Fischer used the discount rate WACC= 6.46%. When we use this same WACC, the NPV of the Base Scenario is R$1,501 million. Which is the same value calculated by Leigh Fischer.

However, the Brazilian Department of the Treasury – STN, through Technical Note Nº 675/2013/STN/SEAE/MF, updated the WACC value to 6.63% per year. Therefore, we use the updated WACC value of 6.63%, as a result, the NPV of the Base Case changed to R$ 1,444 million. For comparison purposes, in the following sections, we will use the NPV of R$1,444 million, with updated WACC. It is worth noting that this Base Scenario does not include the impact of including the proposed mechanism, nor any type of flexibility.

5.5.1. Modeling Demand Uncertainty

The uncertainty of demand is the main risk in the Airport concession. In the literature, passenger demand is usually modeled using Geometric Brownian Motion (GBM) (Black and Scholes, 1973). Concerning airports, Marques et al., (2019) also used GBM to model passenger demand at Galeão Airport. Therefore, we assume that airport passenger traffic varies stochastically following a GBM, as shown in equation (13):

$$dS = \mu S dt + \sigma S dz \qquad (13)$$

Where:

dS: incremental variation of passenger demand,
μ: expected growth rate of passenger demand,
dt: interval of time,
σ: volatility of passenger demand
dz: $\varepsilon\sqrt{dt}$ is the standard Wiener Process, where $\varepsilon \approx N(0,1)$.

Equation 2 of the GBM process can be modeled discretely over annual time intervals, using equation (14) (Brandao and Saraiva, 2008).

$$S_{t+1} = S_t e^{\left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \sigma\varepsilon\sqrt{\Delta t}} \qquad (14)$$

We calculated volatility (σ) using the standard deviation of the logarithmic returns from the historical passenger series of Galeão Airport. For this study, we used the data series from 1990-2017. We chose this range of years because: (i) it represents the period before COVID-19 and, (ii) it shows the growth trend of passengers at Galeão Airport (see Figure 5.5). Thus, we estimated a volatility value of $\sigma = 17.49\%$. The expected growth rate of passenger demand (μ) over the 25-year duration of the project is known and was used to calculate the NPV. Next, we used Monte Carlo Simulation (MCS) to model the Base Scenario, with cash flows varying stochastically. This simulation resulted in a PV of R$ 1.4 billion, which is similar to the PV from static analysis.

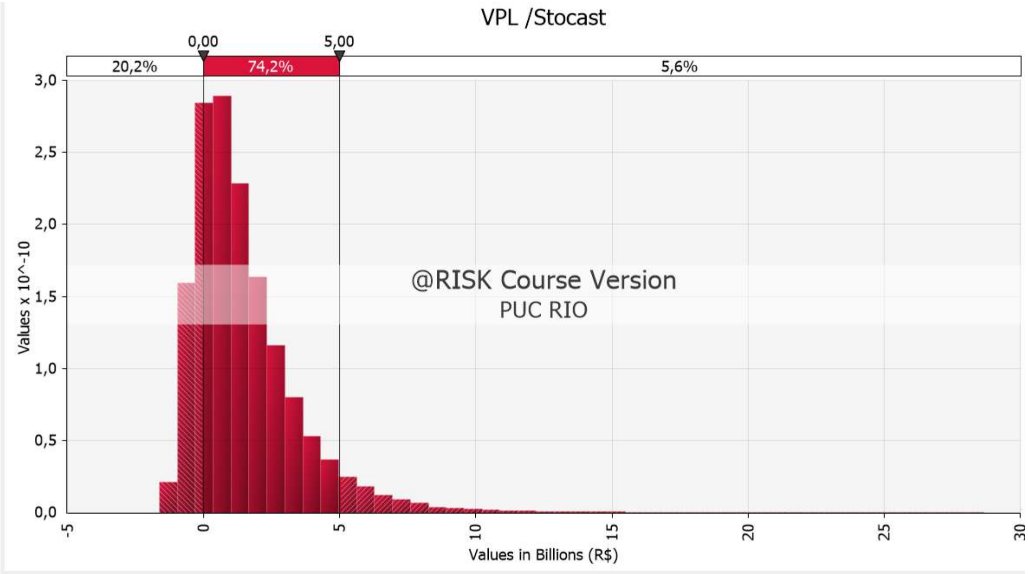

Figure 5.6 – Distribution of the Present Value of Galeão Airport cash flow in the base scenario.

The simulation showed that there is a high probability that the NPV is less than 5 billion, with a 45% chance of obtaining an NPV of 1 billion. As the Grant Value was not included in the Cash Flow (Leigh Fischer) modeling, comparing these probabilities with the minimum grant value (in the notice of 4.8 billion), we observe that the project has a high likelihood of only generating the minimum grant value.

As the inclusion of the mechanism changes the risk of the project, we use the risk-neutral measure to evaluate the options. Therefore, we need to calculate the risk premium and discount it from the passenger demand growth rates. Equation (15) is used to model the risk-neutral passenger demand.

$$Sn_{t+1} = Sn_t e^{\left(\mu - \delta - \frac{\sigma^2}{2}\right)\Delta t + \sigma\varepsilon\sqrt{\Delta t}} \qquad (15)$$

Where:

Sn_t: Risk-neutral passenger demand

δ: Passenger demand risk premium

To determine the risk premium δ, we followed the methodology used by (Brandão et al., 2012; Sant'Anna et al., 2022). We equate the present value (PV) of the risk-adjusted discounted cash flow with the present value (PV) of the risk-neutral discounted cash flow, as presented in equation (16).

$$\int_{t=1}^{n} E[Cf(S_t)]e^{-\alpha t}dt \; = \int_{t=1}^{n} E[Cf(Sn_t)]e^{-\omega t}dt \qquad (16)$$

Where: α: Risk-adjusted discount rate; and ω: Risk-free rate.

The risk-adjusted cash flow is discounted using the risk-adjusted rate (α). The risk-neutral cash flow is discounted using the risk-free rate (ω).

Marques et al., (2019) determine that the nominal return of 20-year U.S. Treasury bonds is 2.58% per year, the 20-year U.S. inflation rate is equal to 0.71% per year, and the Brazilian risk rate is 3.95% per year. Therefore, using these values and equation (17), we assume that the risk-free rate is 5.78%.

$$\omega = \frac{(1 + \text{nominal return of 20year U.S} + \text{Brazilian risk rate})}{(1 + \text{20year U.S. inflation rate})} - 1 \qquad (17)$$

5.5.2.
Modeling the MRG/GL Mechanism

We analyze the MRG/GL guarantee as a sequence of European Options (Put), with annual maturity. We consider this type because each year the guarantee may or not be exercised. Furthermore, the exercise of options is independent of each other (Sant'Anna et al., 2022).

Throughout the concession period, during which the MRG/GL mechanism is in effect, we scholastically model the realized gross airport revenue. The minimum revenue threshold is modeled as a Put Option in favor of the concessionaire. For each year, there is only one possible outcome: i) Put- in favor of the concessionaire or ii) no exercise of the option.

Therefore, for each year, if the Realized Gross airport revenue is below the minimum Revenue threshold: The European Put Option can generate compensation in favor of the concessionaire equivalent to:

$$Put_n = C_{1n} = \min(RMin_n - RTR_n; TGR_m) \qquad (6)$$

Since TGR_m is the balance generated with grant resources, the exercise of Put_n represents a cost for the granting authority.

Model 1: Higher Grant Value (Global Fixed Grant)

The first stage of the MRG/GL mechanism requires the construction of the Escrow Account (EA), using the Grant Value. The highest grant value criterion was the judgment criterion used in the Galeão Airport auction. In 2013, this was the auction criteria adopted by ANAC to auction airport concessions. According to the concession contract, the concessionaire was obliged to pay the granting authority annual installments of the grant value (bid amount in the auction) (ANAC, 2013b). The annual installment to be paid results from dividing the Total Grant Value by the period of the airport Concession (25 years). Thus, each year, the concessionaire would pay equal annual installments.

In the first model, we build the Escrow Account (EA) by retaining a percentage of the value of equal annual installments. Using equations (1) and (2) we calculate the TGR_m (Total Grant retained, brought to Present Value). The calculation is carried out year by year, without accumulating a balance in the account. Therefore, each year we assess the exercise of the guarantee. If no PUT is exercised or there is a balance available in the account EA (see equation 7), the funds are transferred directly to the granting authority.

Table 5.4 – Amount for building the Escrow Account (EA)

Year	Annual installment (Grant)	25% of the Grant (Retained)	% Retained in PV
2014	R$ 193,121,040	R$ 48,280,260	R$ 45,642,589
2015	R$ 193,121,040	R$ 48,280,260	R$ 43,149,020
2016	R$ 193,121,040	R$ 48,280,260	R$ 40,791,681
2017	R$ 193,121,040	R$ 48,280,260	R$ 38,563,130
2018	R$ 193,121,040	R$ 48,280,260	R$ 36,456,330
2019	R$ 193,121,040	R$ 48,280,260	R$ 34,464,629
2023	R$ 193,121,040	R$ 48,280,260	R$ 27,528,103
2028	R$ 193,121,040	R$ 48,280,260	R$ 20,786,417
2033	R$ 193,121,040	R$ 48,280,260	R$ 15,695,783
2038	R$ 193,121,040	R$ 48,280,260	R$ 11,851,855

In the Galeão Airport concession notice, the minimum grant value was R$ 4,828,026,000.00 Real (4.8 billion Brazilian Real). For modeling purposes, we chose a retention percentage of $\%r = 25\%$. Table 5.4 shows the amounts retained annually in the escrow account, over the 25 years of the concession.

Using equations 3 and 4 we calculate the reference revenues and the lower reference threshold. We chose the value of $a = 10\%$ as the Lower band amplitude.

Table 5.5 presents the reference revenue and the minimum revenue threshold (Floor).

Table 5.5 – Reference revenue and the Minimum revenue threshold

Year	Reference revenue	Reference revenue in PV	Minimum Revenue Threshold in PV $(a = 10\%)$
2014	R$ 252,650,868	R$ 238,847,920	R$ 214,963,128
2015	R$ 251,765,534	R$ 225,007,821	R$ 202,507,039
2016	R$ 269,684,366	R$ 227,854,587	R$ 205,069,129
2017	R$ 272,205,520	R$ 217,420,056	R$ 195,678,050
2018	R$ 280,091,089	R$ 211,496,233	R$ 190,346,610
2019	R$ 290,613,409	R$ 207,452,973	R$ 186,707,676
2023	R$ 336,940,168	R$ 192,114,205	R$ 172,902,784
2028	R$ 401,665,336	R$ 172,931,611	R$ 155,638,450
2033	R$ 478,936,721	R$ 155,701,041	R$ 140,130,937
2038	R$ 569,720,420	R$ 139,855,165	R$ 125,869,648

Then, we simulate stochastic variations in demand, following the GBM. Based on Appendix 4, and the parameters calculated in section 5.5.1 (uncertainty modeling), we calculate the risk-neutral cash flow.

Next, we use the Monte Carlo Simulation to compare the variations in airport revenue with the minimum revenue threshold. To perform the simulations, we used the @Risk software. Finally, we calculate the value of the Put (equation 6), and the balance in the retention account EA (equation 7). Table 5.6 shows the value of the Put and the increase in the project value. Table 5.7 displays the balance in the retention account EA after the mechanism and the total transfer value to the granting authority.

Table 5.6 – Compensation generated by the MRG/GL mechanism (in millions)

$\boldsymbol{PV_{FC}}$	$\boldsymbol{PUT_{MRG/GL}}$	$\boldsymbol{PV_{FC} + PUT_{MRG/GL}}$	$\boldsymbol{\%Put}$
R$ 1,443.57	R$ 269.88	R$ 1,713.45	+18.70%

Table 5.7 – Balance in the EA account (in millions)

$\boldsymbol{BEA_{total}}$	$\boldsymbol{Unretained\ Grant}$ 75%	$\boldsymbol{Total\ Transfer}$	$\boldsymbol{Initial\ total\ Grant\ in\ PV}$	$\boldsymbol{Variation\ of\ Grant}$
R$ 360.48	R$ 1,891.08	R$ 2,251.56	R$ 2,521.45	-10.70%

Table 5.6 shows that the inclusion of the MRG/GL mechanism provided protection during periods of demand drop and increased the project's value by 18.70%. Comparing tables 5.6 and 5.7 we observe that at $a = 10\%$, the mechanism does not significantly impact the transfer of the grant to the granting authority. In this case, the total transfer was R$ 2,251.56 million; a value slightly less than the original Present value of the grant (2,521.44 million).

Model 2: The Highest Initial Grant Offered, with Tiered Retention.

The retention account EA of model 1 is built with a retention percentage $\%r$ applied to the annual grant installments. To increase the balance available in the EA account, we have incorporated a criterion of permanence into model 1. We called this new modification as Model 2.

In Model 2, in the balance (after compensation) in the EA account, instead of the total being transferred to the granting authority, we retain 50% of the balance to be used in the next year. In other words, every year, 50% of the balance after compensation is transferred to the granting authority and the other 50% remains in the account. Therefore, in the following year, the available balance is the sum of the annual retention installment $\%r = 25\%$ and the balance retained from the previous year (50%).

In the modeling of Model 2, we use the same parameters as those employed in Model 1. Table 5.8 displays the compensation values generated by the inclusion of the mechanism in Model 2, and Table 5.9 presents the impact of Model 2 on the transfer of the grant value to the granting authority.

Table 5.8 – Variations in the compensation of the MRG/GL mechanism of Model 2 (in millions)

$\boldsymbol{PV_{FC}}$	$\boldsymbol{PUT_{MRG/GL}}$	$\boldsymbol{PV_{FC} + PUT_{MRG/GL}}$	$\boldsymbol{\%Put}$
R$ 1,443.57	R$ 286,59	R$ 1,730.16	+19,85%

Table 5.9 – Impact on the transfer to the granting authority of Model 2 (in millions)

$\boldsymbol{BEA_{total}}$	$\boldsymbol{Unretained\ Grant}$ 75%	$\boldsymbol{Total\ Transfer}$	$\boldsymbol{Initial\ total\ Grant\ in\ PV}$	$\boldsymbol{Variation\ of\ Grant}$
R$ 343.77	R$ 1,891.08	R$ 2,234.85	R$ 2,521.45	-11,37%

Model 2 with a retention of 50% of the available balance, generated a put value of R$286.59. This value increases the value of the project by 19.85%. Table 5.9 shows that the total transfer to the granting authority was R$ 2,234.85, which is 11.37% lower than the original value of R$ 2,521.45 (without mechanism MRG/GL).

Model 3: The Highest Initial Grant Offered.

Starting in 2019, the airport auction criteria changed to the highest initial bid value (ANAC, 2019). According to this new criterion, the grant value resulting from the auction process must be paid in full on the Concession Contract's signature date. The latest concessions were carried out using this criterion; therefore, we also modeled its applicability in the mechanism (model 3).

As the total Grant Value is paid at the beginning, we only make a single retention. The amount arising from the retention process must be maintained in the EA account throughout the entire period of validity of the mechanism. Since this single retention (at the beginning) involves significant amounts of money, we assume that the balance after compensation should be invested at the SELIC rate, with maturity and annual capitalization.

As the concession approaches its end, the risk of demand drop also decreases. Therefore, it would not make sense to maintain the total balance in the retention account until the end of the MRG/GL mechanism's validity. Consequently, we include rescue triggers in the modeling. Rescue trigger: After a certain period of years, a percentage of the money available in the retention account must be transferred to the granting authority.

In model 3, we begin by building the EA retention account. As retention is done once time and at the beginning, we use a retention rate of $\%r = 50\%$.Using the same minimum grant value of 4,828,026,000.00 real, we retained 50% and built the account with 2,414,013,000 real (value from 2013, auction date). We assume a SELIC rate of 5.78% for the entire period. This SELIC rate is the same as the risk-free rate. This is to avoid the effects of inflation and work at constant values. Therefore, the balance in the EA account at the end of 2014, the date of the first compensation is R$ 1,553.52 million.

Next, we define the Reference Revenue and the minimum revenue threshold using the values from Table 5.5 - Reference Revenue. We also chose the value of

$a = 10\%$ as the amplitude of the lower band. Then, we simulate stochastic variations in demand uncertainty using the same parameters as Model 1. Like in model 1, we employ the Monte Carlo Simulation and the @Risk software to compare variations in airport revenue with the Minimum Revenue threshold. Finally, we calculate the value of the Put =compensation to the concessionaire and the balance in the retention account.

Unlike model 1, at the end of each year, the balance in the EA account after compensation is not transferred to the granting authority. The balance is kept in the account and is invested at the SELIC rate. This process is repeated for all years, during the MRG/GL mechanism's validity. Only when the mechanism's validity expires, the balance in the EA account is transferred to the granting authority.

As model 3 includes rescue triggers, we assume the existence of two triggers. Trigger 1: at the end of the tenth year, - after compensation, 50% of the balance in the EA account must be transferred to the granting authority. Trigger 2: at the end of the twentieth year, - after compensation, 50% of the balance in the EA account must be transferred to the granting authority. Table 5.10 shows the value of the Put, in present value, and Table 5.11 shows the balance in the retention account (EA) in Present Value.

Table 5.10 – Compensation generated by the MRG/GL mechanism, in Model 3

$\boldsymbol{PV_{FC}}$	$\boldsymbol{PUT_{MRG/GL}}$	$\boldsymbol{PV_{FC} + PUT_{MRG/GL}}$	$\%\boldsymbol{Put}$
R$ 1,443.57	R$ 668.35	R$ 2,111.92	+46.30%

In Table 5.10, we observe that the inclusion of the MRG/GL mechanism in the new auction criteria increases the value of the project by 46.30%. Providing greater protection in situations of drop demand.

Table 5.11 – Total transfer to the granting authority in Model 3

$\boldsymbol{BEA_{PV} + Trigger_{PV}}$	$\boldsymbol{Unretained\ Grant}$ 2013	$\boldsymbol{Total\,Transfer}$	$\boldsymbol{Initial\ total\ Grant\ in\ PV}$	$\boldsymbol{Variation\ of\ Grant}$
R$ 1,745.67	R$ 2,414	R$ 4,159.68	4,828.03	-13.84%

Tables 5.10 and 5.11 show that in Model 3, the mechanism increased the project value. However, the impact on the transfer of the grant amount to the granting authority was only reduced by 13.84%. This is a consequence of investing the balance in the EA account at the SELIC rate.

5.6 Sensitivities

The results of the developed models illustrate the operation of the mechanism, the option value, and variations in the project value. The value of the mechanism and its impact on the project value depend fundamentally on the modeling of the uncertainty variable and the parameters of the MRG/GL modeling. The modeling of demand uncertainty in the models of section 5.4.2 depends on the parameters of volatility and the expected growth of demand. With the inclusion of this mechanism, the parameters of the risk-free rate and the risk premium also become relevant. These are fundamental in modeling risk-neutral Cash Flow.

Section 5.5 followed the guidelines established by Leigh Fischer in 2013. Therefore, it is important to illustrate comparisons between variations in the parameters of demand uncertainty modeling. For each of the models in section 5.5.2, we recalculated the option value and its impact on the project by modifying the parameters of volatility and demand growth rate.

Tables 5.12, 5.13, and 5.14 present the variations in the project value (base case), the value of the Put-option of the mechanism, and the variation in the project value for each of the models. The total balance transferred to the granting authority (after the mechanism) is also presented, along with the variation when compared to the original grant value (without the mechanism)

Table 5.12 – Sensitivity in demand modeling in Model 1 (in millions)

$\boldsymbol{Volatility}$ (σ)	**Expeted growth rate** (μ)	$\boldsymbol{PV\ of}$ **base scenario**	$\boldsymbol{PUT_{MRG/GL}}$	$\boldsymbol{\%Put}$	$\boldsymbol{BEA_{total}}$	$\boldsymbol{Variation\ of\ Grant}$
18.90%	3.90%	R$1,191	R$309.09	+25.95%	R$321.27	-12.26%
	1.34%**	R$369.08	R$384.84	+104.27%	R$245.52	-15.26%
26.08%	3.90%	R$1,191	R$343.13	+28.81%	R$287.23	-13.61%
	1.34%**	R$369.08	R$397.29	+107.64%	R$233.07	-15.76%

Table 5.13 – Sensitivity in demand modeling in Model 2 (in millions)

$Volatility$ (σ)	Expeted growth rate (μ)	$PV\ of$ *Base scenario*	$PUT_{MRG/GL}$	$\%Put$	BEA_{total}	$Variation\ of\ Grant$
18.90%	3.90%	R$1,191	R$328.12	+27.55%	R$302.24	-13.01%
	1.34%**	R$369.08	R$405.54	+109.88%	R$224.82	-16.08%
26.08%	3.90%	R$1,191	R$366.71	+30.79%	R$263.65	-14.54%
	1.34%**	R$369.08	R$421.77	+114.28	R$208.59	-16.73%

Table 5.14 – Sensitivity in demand modeling in Model 3 (in millions)

$Volatility$ (σ)	Expeted growth rate (μ)	$PV\ of$ **base scenario**	$PUT_{MRG/GL}$	$\%Put$	$BEA +$ $Trigger$	$Variation\ of\ Grant$
18.90%	3.90%	R$1,191	R$787.12	+66.08%	R$1,626.8	-16.30%
	1.34%**	R$369,08	R$1,045	+283.14%	R$1,369.01	-21.64%
26.08%	3.90%	R$1,191	R$956.14	+80.27%	R$1,457.87	-19.80%
	1.34%**	R$369,08	R$1,143	+309.69%	R$1,271.02	-23.67%

5.6.1. Sensitivity Analysis in the Models.

In the same way that variations in demand depend on the uncertainty modeling parameters, the value of the MRG/GL mechanism depends on the parameters used in the models. These parameters are the retention percentage and the amplitude of the lower reference revenue band (floor). Next, we simulate several variations for these parameters and calculate the value of the MRG/GL mechanism and show the impact of the mechanism on the transfer of grant value to the granting authority. The tables below present the sensitivity values for each of the models. The volatility values marked with an asterisk (*) indicate that they are original modeling values. In other words, they follow the cash flow modeling done by Leigh Fischer.

Table 5.15 – Sensitivity in demand modeling in Model 1 (in millions)

(σ)	(μ)	$\%r$	$\%a$	$PV\ of$ BS	Put	$\%Put$	BEA	$\Delta\ Grant$
***17,49%**	***LF**	50%	*10%***	R$1,443	**R$460.84**	***+31.92%***	**R$799.88**	-18,28%
		50%	*20%*	R$1,443	**R$358.13**	***+24.81%***	**R$902.59**	-14.20%
		50%	*30%*	R$1,443	**R$263.91**	***+18.28%***	**R$996.81**	-10.47%
		75%	*10%***	R$1,443	**R$591.30**	***+40.96%***	**R$1,299**	-23.45%
		75%	*20%*	R$1,443	**R$450.39**	***+31.20%***	**R$1440**	-17.86%
		75%	*30%*	R$1,443	**R$326.35**	***+22.61%***	**R$1,564**	-12.94%
18,90%	3,90%	50%	*10%*	R$1.191	R$538.46	+45.21%	R$722.26	-21.36%
		50%	*20%*	R$1.191	**R$432.38**	+36.30%	**R$828.34**	-17.15%
		50%	*30%*	R$1.191	**R$335.30**	+28.15%	**R$925.42**	-13.30%
		75%	*10%***	R$1.191	**R$697.53**	+58.56%	**R$1,193**	-27.66%
		75%	*20%***	R$1.191	**R$553.84**	+46.50%	**R$1,337**	-21.87%
		75%	*30%*	R$1.191	**R$416.60**	+34.97%	**R$1,474**	-16.52%
	1,34%	50%	*10%*	R$369,08	R$690.08	+186.97%	R$570.64	-27.37%
		50%	*20%*	R$369,08	**R$585.43**	+158.62%	**R$675.29**	-23.22%
		50%	*30%*	R$369,08	**R$477.52**	+129.38%	**R$783.21**	-18.94%
		75%	*10%***	R$369,08	**R$919.72**	+249.19%	**R$971.37**	-36.48%
		75%	*20%***	R$369,08	**R$770.19**	+208.68%	**R$1,120**	-30.55%
		75%	*30%*	R$369,08	**R$617.63**	+167.34%	**R$1,273**	-24.50%
26,08%	3,90%	50%	*10%*	R$1.191	R$620.74	+52.11%	R$639.98	-24.62%
		50%	*20%*	R$1.191	**R$535.35**	+44.94%	**R$725.38**	-21.23%
		50%	*30%*	R$1.191	**R$447.51**	+37.57%	**R$813.21**	-17.75%
		75%	*10%***	R$1.191	**R$839.11**	+70.45%	**R$1,051**	-33.28%
		75%	*20%***	R$1.191	**R$708.14**	+59.33%	**R$1,181**	-28.12%
		75%	*30%*	R$1.191	**R$583.09**	+48.95%	**R$1,308**	-23.13%
	1,34%	50%	*10%*	R$369,08	R$731.96	+198.32%	R$528.76	-29.03%
		50%	*20%*	R$369,08	**R$648.83**	+175.80	**R$611.89**	-25.73%
		50%	*30%*	R$369,08	**R$557.47**	+151.04%	**R$703.25**	-22.11%
		75%	*10%***	R$369,08	**R$1,001**	+271.43%	**R$889.29**	-39.73%
		75%	*20%***	R$369,08	**R$873.69**	+236.72%	**R$1,017**	-34.65%
		75%	*30%*	R$369,08	**R$739.70**	+200.42%	**R$1,151**	-29.34%

Table 5.16 – Sensitivity in demand modeling in Model 2 (in millions)

(σ)	(μ)	$\%r$	$\%a$	$PV\ of$ BS	Put	$\%Put$	BEA	$\Delta\ Grant$
***17,49%**	***LF**	50%	*10%***	R$1,443	**R$475.80**	***+32.86%***	**R$784.92**	-18.87%
		50%	*20%*	R$1,443	**R$369.28**	***+25.58%***	**R$891.45**	-14.65%
		50%	*30%*	R$1,443	**R$271.55**	***+18.81%***	**R$989.18**	-10.77%
		75%	*10%***	R$1,443	**R$602.30**	***+41.72%***	**R$1,288**	-23.89%
		75%	*20%*	R$1,443	**R$458.13**	***+31.74%***	**R$1,432**	-18.17%
		75%	*30%*	R$1,443	**R$331.20**	***+22.94%***	**R$1,539**	-13.14%
18,90%	3,90%	50%	*10%*	R$1.191	R$556.19	+46.69%	R$704.53	-22.06%
		50%	*20%*	R$1.191	**R$446.01**	+37.44%	**R$814.71**	-17.69%
		50%	*30%*	R$1.191	**R$345.06**	+28.97%	**R$915.66**	-13.68%
		75%	*10%***	R$1.191	**R$710.87**	+59.68%	**R$1,180**	-28.19%
		75%	*20%***	R$1.191	**R$563.33**	+47.29%	**R$1,327**	-22.34%
		75%	*30%*	R$1.191	**R$422.80**	+35.50%	**R$1,468**	-16.77%
	1,34%	50%	*10%*	R$369,08	R$711.19	+192.69%	R$549.53	-28.21%
		50%	*20%*	R$369,08	**R$602.53**	+163.25	**R$658.19**	-23.90%
		50%	*30%*	R$369,08	**R$490.71**	+132.95%	**R$770.01**	-19.46%
		75%	*10%***	R$369,08	**R$936.82**	+253.83%	**R$954.26**	-37.15%
		75%	*20%***	R$369,08	**R$783.38**	+212.25%	**R$1,107**	-31.07%
		75%	*30%*	R$369,08	**R$627.01**	+169.88%	**R$1,264**	-24.87%
26,08%	3,90%	50%	*10%*	R$1.191	R$645.94	+54.23%	R$614.78	-25.62%
		50%	*20%*	R$1.191	**R$556.08**	+46.68%	**R$704.64**	-22.05%
		50%	*30%*	R$1.191	**R$463.35**	+38.90%	**R$797.37**	-18.38%
		75%	*10%***	R$1.191	**R$859.63**	+72.17%	**R$1,031**	-34.09%
		75%	*20%***	R$1.191	**R$724.76**	+60.85%	**R$1,166**	-28.74%
		75%	*30%*	R$1.191	**R$594.19**	+49.80%	**R$1,296**	-23.57%
	1,34%	50%	*10%*	R$369,08	R$759.47	+205.77%	R$501.25	-30.12%
		50%	*20%*	R$369,08	**R$672.15**	+182.11	**R$588.58**	-26.66%
		50%	*30%*	R$369,08	**R$576.29**	+156.14%	**R$684.43**	-22.86%
		75%	*10%***	R$369,08	**R$1,025**	+277.42%	**R$866.06**	-40,65%
		75%	*20%***	R$369,08	**R$892.12**	+241.71%	**R$998.96**	-35.38%
		75%	*30%*	R$369,08	**R$753.40**	+204.13%	**R$1,137**	-29.88%

Table 5.17 – Sensitivity in demand modeling in Model 3 (in millions)

(σ)	(μ)	$\%r$	$\%a$	$PV\ of$ BS	Put	$\%Put$	BEA	$\Delta\ Grant$
***17,49%**	***LF**	50%	*10%***	R$1,443	**R$668.35**	***+46.30%***	**R$1,745**	-13.84%
		50%	*20%*	R$1,443	**R$509.17**	***+35.27%***	**R$1,904**	-10.53%
		50%	*30%*	R$1,443	**R$368.17**	***+25.50%***	**R$2,045**	-7.63%
		75%	*10%***	R$1,443	**R$755.99**	***+52.37%***	**R$2,865**	-15.66%
		75%	*20%*	R$1,443	**R$556.43**	***+38.55%***	**R$3,064**	-11.53%
		75%	*30%*	R$1,443	**R$385.62**	***+26.71%***	**R$3,235**	-7.99%
18,90%	3,90%	50%	*10%***	R$1.191	R$787.12	+66.08%	R$1,626	-16.30%
		50%	*20%*	R$1.191	**R$619.84**	+52.04%	**R$1,794**	-12.84%
		50%	*30%*	R$1.191	**R$460.90**	+38.69%	**R$1,953**	-9.55%
		75%	*10%***	R$1.191	**R$909.82**	+76.38%	**R$2,711**	-18.84%
		75%	*20%*	R$1.191	**R$693.12**	+58.19%	**R$2,927**	-14.36%
		75%	*30%*	R$1.191	**R$500.83**	+42.05%	**R$3,120**	-10.37%
	1,34%	50%	*10%***	R$369,08	R$1,045	+283.14%	R$1,369	-21.64%
		50%	*20%*	R$369,08	**R$876.33**	+237.43%	**R$1,537**	-18.15%
		50%	*30%*	R$369,08	**R$703.69**	+190.66%	**R$1,710**	-14.58%
		75%	*10%***	R$369,08	**R$1,249.24**	+338.47%	**R$2371**	-25.87%
		75%	*20%*	R$369,08	**R$1,014**	+274.97%	**R$2,606**	-21.02%
		75%	*30%*	R$369,08	**R$774.50**	+209.85%	**R$2,846**	-16.04%
26,08%	3,90%	50%	*10%***	R$1.191	R$956.14	+80.27%	R$1,457	-19.80%
		50%	*20%*	R$1.191	**R$812.92**	+68.25%	**R$1,602**	-16.84%
		50%	*30%*	R$1.191	**R$663.39**	+55.69%	**R$1,750**	-13.74%
		75%	*10%***	R$1.191	**R$1,153**	+96.84%	**R$2,467**	-23.89%
		75%	*20%*	R$1.191	**R$944.96**	+79.33%	**R$2,676**	-19.57%
		75%	*30%*	R$1.191	**R$744.80**	+62.53%	**R$2876**	-15.43%
	1,34%	50%	*10%*	R$369,08	R$1,143	+309.69%	R$1,271	-23.67%
		50%	*20%*	R$369,08	**R$1,004**	+272.29%	**R$1,409**	-20.82%
		50%	*30%*	R$369,08	**R$850.38**	+230.71%	**R$1,563**	-17.61%
		75%	*10%***	R$369,08	**R$1,407**	+381.36%	**R$2,213**	-29.15%
		75%	*20%***	R$369,08	**R$1,203**	+325.99%	**R$2,417**	-24.92%
		75%	*30%*	R$369,08	**R$972.83**	+264.93%	**R$2,643**	-20.25%

5.7. Discussion of Results

The results show that incorporating the MRG/GL mechanism increases the project's value and mitigates the risk of declining demand. In Model 1, the mechanism increased the project value by 18.70%. Its impact on the transfer of the grant value to the granting authority, i.e., the balance plus the portion of the grant not retained, only had a reduction of 10.70%. In Model 2, it was observed that the MRG/GL mechanism increased the project value by 19.85%, a higher percentage than in Model 1. The transfer of the grant value saw a reduction of 11.37%, an even more significant decrease compared to Model 1.

In Model 3, we observed that the inclusion of the MRG/GL mechanism in the new auction criteria significantly increased the project's value by 46.30%. A considerably higher value compared to Models 1 and 2. The transfer of the grant value to the granting authority experienced a reduction of only 13.84%, a value similar to that of Models 1 and 2. The greater protection generated by Model 3 (46.30%) and the minimal reduction in the grant value (-13.84%) may be attributed to the investment at the SELIC rate. In Model 3, the balance after compensation is reinvested at the SELIC rate, leading to an increase the balance in the account. Consequently, the impact on the transfer of grant value is smaller.

Tables 5.12, 5.13, and 5.14 illustrate the sensitivity of the mechanism to different volatilities and demand growth rates. Overall, it is observed that when the expected growth rate of demand is lower, the mechanism provides greater protection in instances of a decline in demand. However, when there is higher volatility, this protection is even greater (see those marked with two asterisks). Concerning the transfer of the grant value, we observe that the values in Tables 5.12 and 5.13 the values are almost the same. The simulations with a lower demand growth rate yield very similar values, irrespective of volatility. In Table 5.14 of Model 3, it is evident that the mechanism provides greater protection, but it also results in a more significant impact on the transfer of the grant value. Higher volatility led to a more substantial reduction in the transfer of the grant value.

Tables 5.15, 5.16, and 5.17 show the results of parameter sensitivities in the models. In Table 5.15, we observe that for Model 1, a parameter of band amplitude $\%a = 10\%$ in the original modeling generates greater compensation to the concessionaire, regardless of the retention ($\%r$) parameter. For other volatility (σ)

and demand growth rates (μ), $\%a$ values of 10% and 20%, combined with a retention of $\%r = 75\%$, result in higher compensation to the concessionaire. Regarding the transfer of the grant value to the granting authority, there is no consistent pattern repeated in all cases. However, $\%a$ values of 20% and 30%, along with a retention of 50%, exhibit the least impact. In the sensitivity analysis of the original model, a $\%a = 30\%$, combined with retentions $(\%r)$ of 50% and 75%, results in the least impact.

Table 5.16 of Model 2 presents results similar to Model 1 concerning compensation to the concessionaire and the increase in project value. However, regarding the transfer of the grant value, the results are even more dispersed. Only in the original modeling is the result similar to that of Model 1.

When compared according to volatility and demand growth rate, we observed that the results follow the same logic in both models. This is because both models were constructed using the same auction criteria. Unlike Model 1, Model 2 generates greater compensation for the concessionaire and, consequently, a more significant reduction in the transfer of the grant value. This is because, in Model 2, only 50% is transferred annually to the granting authority, and the remaining 50% is kept in the account. This results in a higher balance available in the account the next year, increasing the possibility of providing greater compensation to the concessionaire. Consequently, there is a more significant reduction in transfers to the granting authority.

Table 5.17 of Model 3 shows results that follow the same pattern. Almost all the conducted sensitivities indicate that $\%a = 10\%$ increases the project's value and generates greater compensation to the concessionaire, regardless of the retention value. Regarding the transfer of the grant value to the granting authority, all sensitivities with a $\%a = 30\%$ result in a lower impact, irrespective of the retention percentage. As expected, higher volatility reduces the transfer to the granting authority and, therefore, increases compensation to the concessionaire. However, high volatility, when combined with a low expectation of demand growth, results in greater compensation (put). Consequently, more significant reductions in the transfer of the balance to the granting authority.

Among the three models, the sensitivities of Model 3 demonstrated greater compensation to the concessionaire and, consequently, a more substantial increase in the value of the project. Simultaneously, they also indicated a less negative impact on the transfer of the grant value balance to the granting authority. To choose the best model to use in a concession or PPPs, we suggest taking into account volatility, demand growth rates, and concession auction criteria.

6
Conclusions

One of the fundamental drivers of a country's economic growth and social well-being is the effective development of its infrastructure. However, investing in infrastructure projects often requires substantial capital investment. The public sector often lacks the resources for financial, technical, and operational capacity to carry them out. One solution to promote infrastructure development is concessions and public-private partnerships (PPP). Unfortunately, reality shows that public infrastructure projects often fail to be developed correctly and fulfill their social purpose.

This thesis focused on evaluating infrastructure projects, particularly in Latin America and the Caribbean, with a specific emphasis on concession contracts in Brazil. By incorporating flexible clauses and utilizing the Real Options Approach, the research aimed to address the uncertainties and complexities inherent in such projects. The research identified key factors influencing the success of concessions, such as the importance of flexible evaluation methodologies, the impact of uncertainties on project value, characteristics of concession contracts, and common problems affecting public infrastructure concessions in Brazil.

The second chapter presents a literature review based on academic papers to evaluate infrastructure investment projects using the RO approach. The reviewed papers show the superiority of ROA compared to other valuation approaches and highlight its ability to capture the flexibility and valuing uncertainties. This chapter also shows an increase in the publication of papers that apply ROA to assess infrastructure projects. Although the investigations are carried out in different countries, there is a preponderance to analyzing cases from developing countries. Likewise, most of the papers published focus on analyzing transportation network infrastructure. Most papers consider the existence of a single infrastructure project. The analysis of the effects of a portfolio of infrastructure projects is absent. It is also possible to observe that the identification and modeling of uncertainties depend a lot on the type of infrastructure. The main source of uncertainty modeled by researchers is the uncertainty of demand. In addition to that, infrastructure projects are modeled with one or a maximum of two uncertainties. Papers with more than two uncertainties are rare due to computational complexity. Regarding the techniques used to model the uncertainties, the use of Geometric Brownian motion (GBM) and the Binomial tree stand out. Furthermore, there is a tendency to analyze the effects of using multiple options, which is the coexistence of multiple options simultaneously.

The third chapter presents an analysis of the concession contracts of the airport and terrestrial mobility infrastructure sectors in Brazil. We observed that the structuring of concession contracts has been a process of learning with practice. Over the years, models of concession contracts sought to correct previous errors. This, in order to make them more efficient. There is no recipe for solve problems or guaranteeing the success of a concession. However, we believe that it is important to structure the concession contracts taking into account all factors. We highlight that the critical points to be careful with are:

- Adequate level of demand bands. To make sure that the concessionaire is effectively assuming part of the risk.
- Auction judging criteria structured to limit excessive bidding without real support.
- Demand modeling incorporating flexibility. Since they are very long projects, with an average of 30 years.
- Formulate indemnity mechanisms for cases where the concessionaire give up the concession. In order to achieve a balance between punish opportunistic behavior versus attract private participation.

The fourth chapter analyzes the main characteristics of PPPs concession contracts in Latin America. The analysis of PPPs in Ports shows a type of alternative mechanism, called stage investment, capable of mitigating demand risk and incorporating flexibility. To exemplify the stage investment mechanism, we detail the case of the Terminal Portuário Multipropósito de Salaverry, in Peru. In this case study, the concession contract specifies that construction be carried out in stages. These stages can be triggered if demand reaches a pre-established trigger level. On one hand, this allows for adapting the construction to demand needs. On the other hand, once the trigger is reached, the investment, that was previously optional becomes mandatory. Thus, the concession period offers possibilities to incorporate managerial flexibility. The first is to determine the year in which the triggers for port expansion will be activated. This is of primary importance for both the private partner and the public, as they become mandatory investments. The second is to calculate the value of the expansion (mandatory) if it is activated in the last years of the concession. The third is the option of extending the concession period itself to recover the investment when the trigger is activated in recent years.

Finally, the fifth chapter proposes a strategy to mitigate demand risk, and attract private investment, but without generating a budgetary burden for the granting authority. This mechanism is called the Minimum Revenue Guarantee with Guaranteed Liabilities Mechanism (MRG/GL). To demonstrate the application of the mechanism, the international airport of Rio de Janeiro (Galeão) is used as an illustrative case. The proposed strategy, the MRG/GL mechanism, demonstrated the potential to mitigate demand risk and attract private participation without imposing a budgetary burden on the government.

Initially, the model is built following a sequence of five steps: construction of the Escrow Account (EA), calculation of reference revenue, definition of realized revenue, application of compensation, and calculation of the available balance in the Escrow Account. To study the mechanism against different auction judgment criteria, we evaluated its results in three models. The first model uses the 2013 auction judgment criteria, according to which the concession fee is paid annually in equal installments. In the second model, the same auction criteria are considered, but we assume that the balance in the Escrow Account is maintained (50%) for use in the following year. In the third model, the auction criterion of the total grant value paid at the beginning is used. Which is the criteria currently used in airport auctions.

The results showed that the MRG/GL mechanism increases the value of the project and mitigates the demand risk. The sensitivity analysis showed that when there is greater volatility and lower demand growth prospects, the mechanism provides greater protection. Model 3 has a greater impact on transferring of the grant value to the granting authority. However, even though this value is higher when compared to Models 1 and 2, Model 3 remains more efficient. The sensitivity analysis to different retention rates and demand amplitude (floor) also showed that model 3 is superior to the other two models. It is important to highlight that if the model generates greater protection (put), it also generates a greater negative impact on the transfer of value to the granting authority. In this sense, model 3 generates higher compensations (put), but also a greater reduction in value transfer. However, this reduction is not extreme, so we consider model 3 to be the most efficient and recommended.

Overall, this thesis contributes to advancing knowledge in the evaluation of infrastructure projects by introducing innovative strategies that incorporate flexibility and address critical risk. The results reported in chapters 2 to 5 allowed the overall objective of the thesis to be achieved, showing that it is possible to reduce demand risk, make projects attractive, and simultaneously reduce the possibility of budgetary burden and liabilities for the government.

From a public policy perspective, this thesis makes significant contributions by offering actionable recommendations and innovative strategies to resolve the risk of drop demand. Some important contributions include the following:

- Risk mitigation: The research offers a novel strategy, the MRG/GL mechanism, which effectively mitigates the demand risk in infrastructure projects without burdening the government financially. This can be instrumental for policymakers in structuring concession contracts to attract private investments and ensure project viability;
- Flexible evaluation methodologies: By emphasizing the importance of using flexible evaluation methodologies, this thesis highlights the need for policymakers to adapt to uncertainties and changing conditions in infrastructure projects;
- Equitable risk Allocation: The study provides guidelines for ensuring equitable allocation of risk in concession contracts;
- Enhancing project success: Through thesis offers practical recommendations for improving the performance of infrastructure projects through an analysis of the factors influencing concession success. Policymakers can leverage these insights to address common problems, enhance project efficiency, and increase the likelihood of success.

Despite the mentioned contributions, the main limitations of this thesis include:

- Scope Limitation: The study focused specifically on infrastructure projects in Latin America and the Caribbean, with a primary emphasis on concession contracts in Brazil. This limited geographical scope may restrict the generalizability of the findings to other regions or contexts;
- Data Availability: The availability and quality of data on infrastructure projects and concessions may have posed challenges during the research process. Limited access to comprehensive and up-to-date data could have impacted the depth of the analysis and the robustness of the conclusions;
- Assumption Simplification: The research may have made certain simplifying assumptions in modeling the MRG/GL mechanism and evaluating the impact of flexible evaluation methodologies.

By acknowledging these limitations, future research can address these gaps and enhance the robustness and applicability of findings in the field of infrastructure projects and concessions, as follows:

- Long-term impact assessment: Conduct longitudinal studies to assess the long-term impact of implementing the MRG/GL mechanism and other innovative strategies proposed in this thesis. This can provide insight into the sustainability and effectiveness of these approaches over time;
- Policy evaluation: Evaluate existing public policies and regulatory frameworks governing infrastructure concessions to identify areas for improvement. Assess the alignment of current policies with the recommendations proposed in this thesis and explore opportunities for policy reform;
- Technological innovations: Investigate the role of technological innovations, such as digital platforms, data analytics, and smart infrastructure solutions, in enhancing the efficiency and performance of infrastructure projects. Explore how these innovations can be integrated into concession contracts to optimize project outcomes;
- International comparisons: Compare the concession models and practices in Brazil with those in other countries to identify best practices, lessons learned, and opportunities for cross-border collaboration. This comparative analysis can enrich the understanding of global trends in infrastructure concessions.

Future studies can further advance knowledge in the field of infrastructure projects and concessions, contribute to policy development, and enhance the sustainability and effectiveness of infrastructure investments.

7
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8 Appendix

Appendix 1 - Summary of the principal information of the reviewed papers

Reference	Journal	Contract type	Project Type / Country	Research objective	Option/ guarantee type	Valuation method	Uncertainty	Uncertainty modeling	Type of analysis / Calculated variable
(D'Halluin et al., 2002)	IEEE/ACM Transactions on Networking	Not specified/	Telecommuni-cations / US	Determine the optimal timing to investment into new capacity.	Optimal timing to investment.	PDE	Demand for capacity).	Stochastic process.	Individual effects / Optimal Time
(Defilippi, 2004)	Maritime Economics and Logistics	Concession/ Not specified	Port/ Peru	Analyze two concession options and determine the amount of subsidy to grant.	Invest (choice the best option for concession).	MCS. Black & Scholes model.	Costs. Tariffs.	Normal distribution.	Individual effects / Value
(Garvin & Cheah, 2004)	Construction Management and Economics	PPPs / BOT	Toll road / US	Analyze and assess strategic considerations.	Defer option.	Binominal lattice model.	Traffic.	Binomial tree.	Individual effects / Value
(Bowe & Lee, 2004)	Journal of Asian Economics	PPPs / BOT	Rail system / Taiwan	Assess flexibilities individually and with interaction.	Multiple embedded options: Expand, Contract, Defer.	Logtransformed Binominal model.	Revenues (Operation).	Arithmetic Brownian motion.	Individual and Interaction effects / Value
(Huang & Chou, 2006)	Construction Management and Economics	PPPs / BOT	Rail system / Taiwan	Calculate the value of the options in the pre-construction stage.	Abandon option. Minimum Revenue Guarantee (MRG).	PDE	Revenues.	Generalized Wiener process.	Interaction effects / Value
(Cheah & Liu, 2006)	Construction Management and Economics	PPPs / BOT	Bridge / Malaysia	Calculate the total value of the subsidy that the Malaysian government pay as compensation.	Subsidy (elements of a contractual package).	MCS	Traffic.	Lognormal and Normal distribution.	Individual effects / Value
(Chiara et al., 2007)	Journal of Infrastructure Systems	PPPs / BOT	toll road /Not specified	Determine the fair value of that guarantee.	Minimum Revenue Guarantee.	Multi-least-squares Monte Carlo.	Traffic volume.	Random variable with a dynamic variance.	Individual effects / Value
(Alonso-Conde et al., 2007)	Review of Financial Economics	PPPs/ BFOM	toll road / Australia	Assess the incentives	Option to delay payments. Option to cancel early the concession.	MCS	Traffic volumes. Price charged.	Binomial tree.	Interaction effects / Value
(Cui et al., 2008)	Journal of Construction Engineering and Management	Not specified	Highway/United States	Evaluate the value and effectiveness of the ceiling clause.	Warranty	Binomial tree.	Maintenance expenditures	Binomial tree.	Individual effects / Value

(Brandao & Saraiva, 2008)	Construction Management and Economics,	PPPs/ Not specified	toll road / Brazil	Determine the optimal level of guarantees and caps.	Minimum traffic guarantee (MTG).	MCS	Traffic.	GBM	Individual effects / Level
(Iyer & Sagheer, 2011)	Construction Management and Economics	PPPs / BOT	toll road / India	Determine the appropriate level of traffic band.	Traffic band (traffic floor and traffic cap).	Binominal lattice model.	Traffic demand.	GBM	Individual effects / Level
(Brandao et al., 2012)	Journal of Infrastructure Systems	PPPs / BOT	Subway / Brazil	Assess the value and impacts of the risk mitigation mechanism adopted.	Subsidy payments. Minimum Demand Guarantee (MDG).	MCS	Traffic.	GBM	Individual and Interaction effects / Value
(Krüger, 2012)	Transportation Research Part A: Policy and Practice	PPPs/ Not specified	Tollroad / Sweden	Determine the value of the option.	Expansion option.	Decision tree	Traffic.	Binomial tree.	Individual effects / Value
(Ashuri et al., 2012)	Journal of Construction Engineering and Management	PPPs / BOT	Highway / South Korea	Calculate the correct value of MRG option.	Minimum Revenue Guarantee.	Risk-neutral binomial lattice.	Traffic.	Binomial tree.	Individual effects / Value
(Doan & Menyah, 2013)	Journal of Construction Engineering and Management	PPPs / BOT	Tollroad / Not specified	Determine the value of deferral option of the construction project start-up.	Defer option.	Binomial lattice valuation model.	Traffic Operation and maintenance Expenses.	MRP. GBM.	Individual effects / Value
(Cabral & Silva, 2013)	European Sport Management Quarterly	PPPs /Not specified	Stadiums / Brazil	Determine the incentive and size of the incentive for the private sector to participate.	Guarantee a Minimum Demand.	Binomial tree model. MCS.	Demand (attendance at matches)	GBM	Individual effects / Value
(Park et al., 2013)	Journal of Construction Engineering and Management	PPPs/ Not specified	Water and Sewer systems / US	Evaluate the feasibility of the project. Balance the income and expenses of the MEL and MRL options.	Maximum revenue limit (MRL). Maximum expense limit (MEL).	MCS (for MRL). Binominal lattice model (for MEL).	Operation and maintenance (O&M) expenses.	Marketed asset disclaimer	Interaction effects / Value
(Cruz & Marques, 2013)	International Journal of Project Management	PPPs/ DFBO	Hospital / Portugal	Determine the value of the flexible expansion option	Flexible expansion.	Binominal lattice model. MCS.	Demand (of patients).	Binomial tree.	Individual effects / Value
(Martins et al., 2014)	Journal of Air Transport Management	PPPs/ Not specified	Airport / Portugal	Determine the increase in value if the contract included a flexible option.	Expansion option (phased investment option).	MCS	Traffic.	Binomial tree.	Individual effects / Value
(Carbonara et al., 2014)	Construction Management and Economics	PPPs / BOT	Tollroad / Italy	Develop a model to determine the revenue guarantee level and the value of the 'revenue cap'.	Minimum revenue guarantee (MRG).	MCS	Traffic.	GBM	Individual effects / Level
(Lara-Galera et al., 2016)	Revista de la Construccion	Not specified	Highway / Spain	Determine the value of the participation loans.	Participation loans.	MCS	Traffic.	GBM	Individual effects / Value

(Liu et al., 2017)	Journal of Construction Engineering and Management	PPPs/ Not specified	Highway/ Not specified	Evaluate and compare various government financial support mechanisms.	Availability payments. Minimum revenue guarantees (MRGs). Flexible-term contracts.	MCS	Traffic.	GBM	Individual effects / Value
(Martins et al., 2017)	Transportation Planning and Technology	Concession /Not specified	Port / Spain	Analyze the incorporation of flexibility in port planning physical infrastructure.	Expansion option.	MCS	Traffic (container cargo).	Binomial tree.	Individual effects / Value
(Attarzadeh et al., 2017)	Construction Management and Economics	PPPs / BOT	Freeway / Iran	Assess the early fund generation and calculate the equitable bound for a guaranteed revenue.	Early fund generation (EFG) option. (MinMax- Guaranteed revenue option).	Black and Scholes model with PDE.	Traffic volume.	Triangular fuzzy number	Interaction effects / Level
(Buyukyoran & Gundes, 2017)	Construction Management and Economics	PPPs / BOT	Tollroad / Not specified	Identification of optimum boundaries (upper and lower) of compound MRG and Maximum Revenue Cap (MRC) options.	Minimum Revenue Guarantees (MRGs). Maximum Revenue Cap (MRC).	MCS. Ojective function.	Traffic.	GBM	Interaction effects / (Levels (identify the fair values))
(Colín et al., 2017)	Journal of Infrastructure System	PPPs/ Not specified	Motorway / Spain	Assess the value of the compensation mechanism (modeled as an abandonment option).	Abandon option.	MCS	Traffic volume.	GBM	Individual effects / Value
(Zapata Quimbayo et al., 2018)	Construction Management and Economics	PPPs/ BOMT	Tollroad / Colombia	Determine the process that will best model the future traffic levels.	Minimum Revenue Guarantee (MRG).	MCS	Traffic.	MRP	Individual effects / Value
(Lara Galera et al., 2018)	Journal of Infrastructure Systems	PPPs/ Not specified	Motorway / Spain	Assess the value of a public subsidy.	Subsidy.	MCS	Traffic volume.	GBM	Individual effects/ Value
(Carbonara & Pellegrino, 2018)	Construction Management and Economics	PPPs / BOT	Bridge / Italy	Determine the optimal values of the revenue floor and revenue ceiling for a "win–win" condition.	Revenue guarantee.	MCS	Traffic.	GBM	Individual effects / (Value / Level)
(Ihm et al., 2019)	KSCE Journal of Civil Engineering	Not specified	Water infrastructures / South Korea	Economic feasibility of project.	Invest option. Delay option. Abort option.	Decision Tree	Climate risk (drought).	Binomial tree.	Individual effects / Value
(Marques et al., 2019)	Latin American Business Review	Concession/ BOT	Airport / Brazil	Determine whether the concessionaire correctly priced the offer or whether it bid in excess.	Expansion option.	Binominal lattice model.	Traffic (passenger demand).	GBM	Individual effect / Value
(Oliveira et al., 2020)	Research in Transportation Economics	Not specified	Airport / Portugal	Assess whether it is worth to implement an additional investment.	Expansion (multistage) option.	Binomial backward procedures.	Traffic (Number of flights).	Binomial tree.	Individual effects / Value
(Pimentel et al., 2020)	Research in Transportation Economics	Not specified	Port / Portugal	Level of EU financial aid (co-funding rate).	Expansion option.	Binominal lattice model.	Traffic	Binomial tree.	Individual effects / Level

(Kim & Li, 2020)	Transportation Research Part A: Policy and Practice	Not specified	Transportation / Canada	When to construct an all-weather highway or how long should we defer.	Defer all-weather highway construction.	Binominal lattice model.	Climate risk (open season days).	GBM MCS	Individual effects / Optimal Time
(Balliauw & Onghena, 2020)	Journal of Air Transport Management	Not specified	Airport / EU	Optimize both the timing and the size to invest of a one-shot.	Invest (capacity expansion decision).	Dynamic programming. Queuing theory.	Demand for airport movements.	GBM	Interaction effects (time and size) / Optimal time
(Balliauw et al., 2020)	Case Studies on Transport Policy	Concession/ Not specified	Port / (Italy and Angola)	Determine the size and optimal timing of the investment decision.	Invest (capacity expansion decision).	Numerical simulation. Dynamic programming.	Traffic	GBM	Interaction effects (time and size) / Optimal time
(Polat & Battal, 2021)	Journal of Air Transport Management	PPPs / BOT	Airport / Turkey	Determine the value and the best time to expand.	Multi-stage growth (compound real options).	PDE	Revenue risk. Volatility of the project.	Determined MCS	Individual effects / Value
(Jin et al., 2021)	European Journal of Operational Research	PPPs / BOT	Highway / China	Determine the values of the concession period (optimal length) and level of the MRG. Combined values.	Concession period. Minimum revenue guarantee.	MCS	Traffic volume.	GBM	Interaction effects (range) / Value
(Marques et al., 2021)	Construction Management and Economics	PPPs / BOT	Tollroad / Brazil	Evaluate expansion policies that allow the crossing of the Brownian Bridge	Optional capacity expansion. Term extension policies.	Binominal lattice model.	Traffic volume.	GBM	Individual effects / Value

Note: GBM - Geometric Brownian Motion, MRP - Mean Reverting process, MCS - Monte Carlo simulation, PDE - Partial differential equation.

Appendix 2 - Characteristics of concession contracts

Date (signature -end)	Entity	Model	Project	Type of Project	Auction Qualification Criteria	Auction Result	Term (years)	Trigger	Situation
2006 - 2039	PE	SC	Rota dos Coqueiros	Highway	Lower value of government monetary compensation	–	33	–	In operation
2006 - 2038	SP	SC	Linha 4 - Amarela	Metro	Lower value of government monetary compensation	–	32	–	In operation
2007 - 2032	MG	SC	Rodovia MG 050	Highway	Lower value of government monetary compensation	–	25	–	In operation
2013-2038	SP	SC	Linha 6 - Laranja	Metro	Lower value of government monetary compensation	Discount: 0,004%	25	–	*In December 2018, was declared the forfeiture of the contract.
2013 - 2038	RJ	SC	VLT Carioca	VLT	Lower value of government monetary compensation / Parcel A.	Discount: 1,35%	25	–	In operation
2013 - 2043	BA	SC	Projeto Metrô de Salvador e Lauro de Freitas	Subway	Lower value of government monetary compensation / Monthly proportional	Discount: 5,05%	30	–	In operation
2014 - 2039	SP	SC	Linha 18 – Bronze	Monorail	Lower value of government monetary compensation		25	–	In August 2020, was published the Extinction
2014 - 2044	SP	SC	Rodovia Tamoios (3a etapa)	Highway	Lower value of government monetary compensation		30	–	In operation
2014 - 2044	MG	SC	Aeroporto Regional da Zona da Mata	Airport	Lower value of government monetary compensation	Discount: 32 %	30	–	In operation
2015 - 2035	SP	SC	SIM (modal VLT)	VLT	Lower value of government monetary compensation		20	–	In operation
2017 - 2047	SP	CC	05 Aeródromos Públicos - Aviação Executiva	Airport	Highest grant value / Fixed	Premium: 101%	30	–	In operation

2017 - 2047	SP	CC	Concessão de Rodovias (4a etapa - Centro Oeste Paulista e Rodovias Calçados)	Highways	Highest grant value / Fixed	Premium: 131 % (Centro Oeste) and 438 % (Calçados)	30	–	In operation
2018 - 2048	MG	SC	Rodovias do Lote BR-135	Highway	Highest grant value / throughout the concession term	–	30	–	In operation
2018 - 2038	SP	CC	Linha 05 Lilás e Linha 17 (Monotrilho)Ouro	METRÔ	Highest grant value / Fixed	Premium: 185%	20	–	In operation
2018 - 2038	BA	SC	Rodoviário BA052 (Estrada do Feijão)	Highway	Lower value of government monetary compensation / maximum per year	Discount: 0 %	20	–	In operation
2019 - 2039	BA	SC	VLT de Salvador	VLT	Lower value of government monetary compensation / maximum per year	Discount: 0,01%	20	–	In operation
2020 - 2050	SP	CC	PIPA - Piracicaba-Panorama	Road	Highest grant value / Fixed	Premium: 7 209,25%	30	–	In operation
2020 - 2055	BA	SC	Projeto Sistema Rodoviário Ponte Salvador - Ilha de Itaparica	Bridge	Lower value of government monetary compensation / maximum per year	Discount: 0%	35	–	In operation
2020 - 2050	MS	CC	Rodovia MS-306	Highway	Highest grant value / (Initial Fixed Grant and Annual Fixed Grant)		30	–	In operation
2021 - 2051	PI	SC	Projeto Transcerrados – Rodovia PI-397	Highway	Lower value of government monetary compensation / maximum per month	Discount: 1,5%	30		In operation
2021 - 2051	SP	CC	Linha 08 Diamante e Linha 09 Esmeralda	Trains	Highest grant value / Fixed grant	Premium: 205,56%	30	–	In operation
2022 - 2052	MG	CC	Aeroporto da Pampulha	Airport	Highest grant value / Fixed grant	Goodwill of 245,29%	30	–	In operation
2022 - 2052	SP	CC	Concessão dos Aeroportos Regionais e de Aviação Executiva	Airport	Highest grant value / Fixed grant	Premium: *Bloco Noroeste (11,14% *Bloco Sudeste (11,5%)	30	–	In operation

2022 - 2054	PI	SC	Aeroporto Parnaíba	Airport	Lower value of government monetary compensation / maximum per month	–	32	–	In operation
1994 - 2014	F-ANTT	CC	CCR Ponte	Bridge	Lowest value of Basic Toll Fare	Discount: 61%	20	–	Concession with terminated Contract.
1995 - 2020	F-DNER	CC	CONCER	Highway	Lowest value of Basic Toll Fare	Discount: 4,5%	25		In operation
1995 - 2020	F-DNER	CC	BR-116/RJ CRT	Highway	Lowest value of Basic Toll Fare		25	–	Concession with terminated Contract.
1995 - 2020	Federal/ DNER	CC	Nova Dutra	Highway	Lowest value of Basic Toll Fare	Discount: 4,4%	25	–	Concession with terminated Contract.
1997 - 2017	Federa/D NER	CC	CONCEPA	Highway	Lowest value of Basic Toll Fare	Discount: 60%	20	–	Concession with terminated Contract.
1998 - 2026	F- DAER/RS	CC	Ecosul	Highway	Lowest value of Basic Toll Fare	-	28	–	In operation
2008 - 2033	F-ANTT	CC	Autopista Fernão Dias	Highway	Lowest value of Basic Toll Fare	Discount: 65,43%	25	–	In operation
2008 - 2033	F-ANTT	CC	Autopista Fluminense	Highway	Lowest value of Basic Toll Fare	Discount: 40,95%	25	–	*In March 2022, was qualified the re-bidding.
2008 - 2033	F-ANTT	CC	Autopista Litoral Sul	Highway	Lowest value of Basic Toll Fare	Discount: 62,67%	25	–	In operation
2008 - 2033	F-ANTT	CC	Autopista Planalto Sul	Highway	Lowest value of Basic Toll Fare	Discount: 39,35%	25	–	In operation
2008 - 2033	F-ANTT	CC	Régis Bittencourt	Highway	Lowest value of Basic Toll Fare	Discount: 49,20%	25	–	In operation
2008 - 2033	F-ANTT	CC	Rodovia Transbrasiliana	Highway	Lowest value of Basic Toll Fare	Discount: 40%	25	–	In operation
2008 - 2033	F-ANTT	CC	Rodovia do Aço	Highway	Lowest value of Basic Toll Fare	Discount: 27%	25	–	In operation
2009 - 2034	F-ANTT	CC	Via Bahia	Highway	Lowest value of Basic Toll Fare	Discount: 21%	25	VT	*In 2021, the forfeiture process was opened. *In 2022, was archived the forfeiture.

2013 - 2043	F-ANTT	CC	ECO050 - (antiga MGO)	Highway	Lowest value of Basic Toll Fare	Discount: 42%	30	VT	In operation
2013 - 2038	F-ANTT	CC	ECO101	Highway	Lowest value of Basic Toll Fare	Discount: 45,63%.	25	VT	*In July 2022, Eco101 gives up the BR-101 concession in Espírito Santo and Bahia.
2014 - 2044	F-ANTT	CC	CONCEBRA	Highway	Lowest value of Basic Toll Fare	Discount: 52%	30	VT	In 2021, was approved the rebidding.
2014 - 2044	F-ANTT	CC	Galvão BR-153	Highway	Lowest value of Basic Toll Fare	Discount: 45,99%	30	VT	Concession with declared forfeiture.
2014 - 2044	F-ANTT	CC	Rota do Oeste	Highway	Lowest value of Basic Toll Fare	Discount: 52,03%	30	VT	In the process of re-bidding.
2014 - 2044	F-ANTT	CC	VIA 040	Highway	Lowest value of Basic Toll Fare	Discount: 61,13%	30	VT	In the process of re-bidding.
2014 - 2044	F-ANTT	CC	MS VIA	Highway	Lowest value of Basic Toll Fare	Discount: 52,74%.	30	VT	In the process of re-bidding.
2015 - 2045	F-ANTT	CC	ECOPONTE	Bridge	Lowest value of Basic Toll Fare	Discount: 36,67%	30	–	In operation
2019 - 2049	F-ANTT	CC	Ecovias do Cerrado	Highway	Lowest value of Basic Toll Fare	Discount: 33,14%	30	VT	In operation
2019 - 2049	F-ANTT	CC	Rodovias Integradas do Sul - ViaSul	Highway	Lowest value of Basic Toll Fare	Discount: 40,53%	30	VT	In operation
2020 - 2050	F-ANTT	CC	CCR ViaCosteira	Highway	Lowest value of Basic Toll Fare	Discount: 62%	30	VT	In operation
2021 - 2056	F-ANTT	CC	Ecovias do Araguaia	Highway	Hybrid criteria Lowest value of Basic Toll Fare (limited discount) -The highest grant value (tie-breaking criteria)	Discount: 16,25% (Maximum discount allowed)	35	VT	In operation
2022 - 2052	F-ANTT	CC	EcoRioMinas	Highway	Hybrid criteria Lowest value of Basic Toll Fare (limited discount) -The highest grant value (tie-breaking criteria)	Discount: 3.11 %	30	VT	In operation

2022 - 2032	F-ANTT	CC	Via Brasil	Highway	Lowest value of Basic Toll Fare	Discount: 8,098%	10	–	In operation
2022 - 2052	F-ANTT	CC	CCR Rio/SP	Highway	Hybrid criteria The lowest toll fare value (limited discount) The highest grant value (tie-breaking criteria)	Discount: 15.31% (Maximum discount allowed)	30	VT	In operation
2011 - 2040	F-ANAC 1ª Rodada	CC	Aeroporto International de NATAL	Airport	Higher grant value / per year	Premium: 228,8%	28	IT	In 2020, it was declared in the process of Rebidding.
2012 - 2042	F-ANAC 2º rodada	CC	Viracopos (SP)/ CAMPINAS	Airport	Higher grant value / Global fixed grant	Premium: 159,75%	30	IT	In the process of re-bidding.
2012 - 2032	F-ANAC 2º rodada	CC	Aeroporto Internacional de Guarulhos (SP)	Airport	Higher grant value / Global fixed grant	Premium: 373,5 %	20	IT	In operation
2012 - 2037	F-ANAC 2º rodada	CC	Aeroporto Internacional Juscelino Kubitschek-Brasília	Airport	Higher grant value / Global fixed grant	Premium: 673,39%	25	IT	In operation
2013 - 2044	F-ANAC 3ª rodada	CC	Aeroporto Internacional Tancredo Neves/Confins (MG)	Airport	Higher grant value / Global fixed grant	Premium: 66%	30	IT	In operation
2013 - 2039	F-ANAC 3ª rodada	CC	Aeroporto Internacional do Rio de Janeiro/Galeão	Airport	Higher grant value / Global fixed grant	Premium: 294%	25	IT	In June 2022, the rebidding was approved.
2017 - 2047	F-ANAC 4ª rodada	CC	Aeroporto de Salvador - Deputado Luís Eduardo Magalhães	Airport	Higher grant value/ Initial Fixed Grant offered	Premium: 113,25%	30	IT	In operation
2017 - 2042	F-ANAC 4ª rodada	CC	Aeroporto de porto Alegre - Salgado filho Porto Alegre (RS)	Airport	Higher grant value/ Initial Fixed Grant offered	Premium: 852%	25	IT	In operation
2017 - 2047	F-ANAC 4ª rodada	CC	Aeroporto internacional de fortaleza (CE) - Pinto martins	Airport	Higher grant value/ Initial Fixed Grant offered	Premium: 18%	30	IT	In operation
2017 - 2047	F-ANAC 4ª rodada	CC	Aeroporto de florianópolis (SC) - Hercílio luz	Airport	Higher grant value/ Initial Fixed Grant offered	Premium: 58%	30	IT	In operation
2019 - 2049	F-ANAC Bloco Sudeste 5ª Rodada	CC	Aeroporto Vitória/ES - Eurico de Aguiar Salles; Aeroporto Macaé/RJ	Airport	The highest initial grant offered	Premium: 830%	30	IT	In operation

2019 - 2049	F-ANAC Bloco Nordeste 5ª rodada	CC	Aeroporto Internacional do Recife/Guararapes – Gilberto Freyre; Aeroporto de Maceió – Zumbi dos Palmares; Aeroporto Internacional Santa Maria – Aracaju; Aeroporto de Campina Grande – João Suassuna; Aeroporto Internacional de João Pessoa – Presidente Castro Pinto; Aeroporto de Juazeiro do Norte – Orlando Bezerra Menezes.	Airport	The highest initial grant offered	Premium: 1.010%	30	IT	In operation
2019 - 2049	F-ANAC Bloco Centro-Oeste 5ª rodada	CC	Aeroporto Internacional de Cuiabá - Marechal Rondon Aeroporto de Rondonópolis; Aeroporto de Alta Floresta Aeroporto de Sinop - Presidente João Figueiredo	Airport	The highest initial grant offered	Premium: 4.739 %	30	IT	In operation
2021 - 2051	F-ANAC Bloco Sul 6ª Rodada	CC	Aeroporto de Curitiba/PR – Afonso Pena Aeroporto de Foz do Iguaçu/PR – Cataratas Aeroporto de Navegantes/SC – Ministro Victor Konder Aeroporto de Londrina/PR – Governador José Richa Aeroporto de Joinville/SC – Lauro Carneiro de Loyola Aeroporto de Bacacheri/PR Aeroporto de Pelotas/RS Aeroporto de Uruguaiana/RS – Rubem Berta Aeroporto de Bagé/RS – Comandante Gustavo Kraemer	Airport	The highest initial grant offered	Premium: 1 534%	30	IT	In operation

2021 - 2051	F-ANAC Bloco Norte 6ª Rodada	CC	Aeroporto Internacional de Manaus / AM – Eduardo Gomes Aeroporto de Porto Velho / RO – Governador Jorge Teixeira de Oliveira Aeroporto de Rio Branco / AC - Plácido de Castro Aeroporto de Cruzeiro do Sul / AC Aeroporto de Tabatinga / AM Aeroporto de Tefé / AM Aeroporto de Boa Vista / RR – Atlas Brasil Cantanhede.	Airport	The highest initial grant offered	Premium: 777%	30	IT	In operation
2021 - 2051	F-ANAC Bloco Central 6ª Rodada	CC	Aeroporto de Goiânia / GO – Santa Genoveva; Aeroporto de São Luís / MA – Marechal Cunha Machado Aeroporto de Teresina / PI – Senador Petrônio Portella Aeroporto de Palmas / TO – Brigadeiro Lysias Rodrigues Aeroporto de Petrolina / PE – Senador Nilo Coelho Aeroporto de Imperatriz / MA – Prefeito Renato Moreira	Airport	The highest initial grant offered	Premium: 9.156%	30	IT	In operation
2022-2052	Bloco Aviação Geral 7ª Rodada	CC	Aeroporto Campo de Marte(SP) Aeroporto de Jacarepaguá - Roberto Marinho (RJ)	Airport	The highest initial grant offered	Premium: 0,01%	30	IT	Recently Auctioned
2022 - 2052	Bloco Norte II 7ª Rodada	CC	Aeroporto Internacional Val-de-Cans, Belém (PA) Aeroporto Internacional Alberto Alcolumbre, Macapá (AP)	Airport	The highest initial grant offered	Premium: 119,78%	30	IT	Recently Auctioned

2022 - 2052	Bloco SP/MS/PA/MG 7ª Rodada	CC	Aeroporto de Congonhas (SP) Aeroporto de Campo Grande (MS) Aeroporto de Corumbá (MS) Aeroporto Internacional de Ponta Porã (MS) Aeroporto Maestro Wilson Fonseca, Santarém (PA) Aeroporto João Corrêa da Rocha, Marabá (PA) Aeroporto Carajás, Parauapebas (PA) Aeroporto de Altamira (PA) Aeroporto César Bombonato, Uberlândia (MG) Aeroporto Mário Ribeiro, Montes Claros (MG) Aeroporto Mario de Almeida Franco, Uberaba (MG)	Airport	The highest initial grant offered	Premium: 231,02%	30	IT	Recently Auctioned

Note: The acronyms are: SC= Sponsored Concession, CC = Common Concession, SP= State of São Paulo, PE=State of Pernambuco, PI=State of Piauí, RJ=State of Rio de Janeiro, MS= State of Mato Grosso do Sul, BA =State of Bahia, F-ANTT=Federal/ ANTT, F - ANAC=Federal /ANAC, F-DNER= Federal/DNER, F-DAER/RS=Federal/ State of Rio Grande do SuI (DAER/RS), VT = Volumetric Trigger, IT= Investment Trigger and VLT = Light Rail Vehicle.

Appendix 3 - Problems in land mobility infrastructure concessions.

Project	Situation	Problems
Linha 6 – Laranja Metro	*In December 2018, was declared the forfeiture of the contract. * In July 2020, the concession was transferred to Concessionaria Linha Universidade S/A (SPE). *In October 2020, the forfeiture decree was revoked. Concession with new term: 28 years.	*Works delayed since 2015. *Request for extension of term for installment of the works. *The execution of the project works only reached 15%. *Difficulties in obtaining long-term financing from the BNDES. *Companies that form part of the Move São Paulo consortium were involved in the investigations of the Lava Jato Operation case. *The concessionaire claimed to have neither a line of credit nor money to carry out the works. * Project was stopped and interrupted for four years.
Linha 18 – Bronze (Monorail)	*In August 2019, the CGPPP - Conselho Gestor de Parcerias Publico-privadas decided to extinguishment of the Concession. *In August 2020, was published the DOE-Extinction extract from the Concession contract.	* The declaration of the beginning of the concession period was not made. *The contract was not officially in operation. *High cost of expropriation of areas for the implementation of stations. *Technical problems with expropriations. *Changes in State Management: implementation of a BRT-Bus Rapid Transit system instead of monorail.
BR-101/RJ – Divisa RJ/ES – Ponte Presidente Costa e Silva **Highway Autopista Fluminense**	*In September 2021, through Resolution Nº. 307, ANTT attested to the technical and legal feasibility of the request for re-bidding *In March 2022, the project was qualified in the PPI for re-bidding, through Decree Nº 11,005.	*The concessionaire argues that it is incapable of fulfilling the established obligations due to financial problems. *The concessionaire claimed to have problems with its financial situation. * Tariff revenues were not enough to cover expenses. *Sudden drop in traffic. *Inability to comply with the planned investments (works and provision of services).
BR 116/324/BA BA 526/528 **Highway Via Bahia**	*In 2021, the concession forfeiture process was opened. Resolution Nº 424. *In 2022, ANTT decided to archive the concession forfeiture process. The forfeiture process was archived.	* Non-payment of penalties or fines. * 295 sanctioning administrative processes (totaling 400 million). * Non-execution rate of almost 100%. *The concessionaire did not pay the fines within the indicated period.

BR 101/ES/BA: **Highway ECO101**	*In July 2022, Eco101 gives up the BR-101 concession in Espírito Santo and Bahia. *Amicable extinction of the concession contract.	*Difficulties in obtaining environmental licensing and financing. *Delays in expropriation and eviction processes. *Decision of the Federal Court of Auditors (TCU) to amend the concession contract. * Non-realization of the BR-116 toll. *Non-completion of Contorno do Mestre Álvaro. * Worsening economic scenario.
BR 060, BR 153 e BR 262 DF / GO / MG **Highway CONCEBRA**	* In 2020, the Concessionaire requested the rebidding of the highways. However, the request was not accepted. *In 2021, the Concessionaire filed a new devolution request. * In November 2021, published in Decree N°. 10,864, the rebidding was approved.	The concessionaire indicates that: *The BNDES financing was not released, therefore, it did not have access to lower interest rates. *Due to lack of funding, the operation and construction of expansion works was unfeasible. *Doubling tracks for only 17.16% of the total 648 km agreed in the contract.
BR-153/TO/GO: Trecho Anápolis/GO (BR-060) até Aliança do Tocantins/TO **Highway Galvão BR-153**	Concession with declared forfeiture. Publication of the forfeiture Decree: August 2017 ANTT, declare the expiry of the Concession in the hypothesis of total or partial non-execution of the Contract.	The government extinguished the concession for non-compliance with the contract. *The concessionaire did not carry out the planned investments. *In 2016, the works were paralyzed, waiting loan and contract extension. *Sections of highways paralyzed since 2015. *Problems of the concessionaire to access the BNDES loan. * Concessionaire involvement in the investigation of the Lava Jato case. Conducted by the federal police.
BR-163/MT - BR-163 e MT-407 do MS até o entroncamento com a MT-220 **Highway Rota do Oeste**	Re-bidding approved at the 21st CPPI, held in June 2022.	The concessionaire requested the forfeiture, and friendly devolution, due to: *Did not comply with the investment obligations established in the contract. *No duplication of roads in the first five years of the concession. *The concessionaire wanted to sell control of the concession to another group (cure plan). Thus, this group would carry out the investment. *An agreement was not reached, because the new group (SIMPAR) withdrew. *The authorization of the RUMO railroad reduced the projected demand. * Difficulties in obtaining financing from the BNDES.

BR-040/DF/GO/MG - Trecho Brasília-DF - Juiz de Fora-MG **Highway VIA 040**	*In January 2020, the Rebidding was approved through Resolution N°. 105. *Rebidding at the stage of studies and public audience. *In the rebidding, it was decided to subdivide the highway into 2 stretches, which will be bid separately.	The concessionaire requested a friendly extinction, due to: *Since 2017, the concessionaire has shown interest in rescind the contract. *Economic losses (in highway operation), linked to the economic crisis. *It did not carry out 87% of the works in the first years of the concession. *Fines due to non-execution of works. *The concessionaire claimed that the delay is due to problems in issuing licenses. *Lack of well-established criteria on economic-financial balance and other fundamental issues. *The concession had political decisions rather than technical decisions.
BR-163/MS - Início na divisa com o estado do MT e término na divisa com o PR **Highway MS VIA**	The rebidding was qualified through Resolution No. 148 of the PPI of December 2020 and Decree No. 10,647 of March 2021. Currently in the process of re-bidding. Project under study	The concessionaire claimed problems, due to: *New rail mode implemented in Rondonópolis (MT), which reduces road traffic and generates losses for the concessionaire. * Lower collection of tolls, therefore the works stopped and their duplication. *The concessionaire only duplicated small intermittent stretches. *Difficulties in complying with highway duplication obligations. * Problems in feasibility modeling. *Economic and financial difficulties.

Appendix 4 - Cash flow of the base scenario, in millions.

CASH FLOW										
In constant 2013 values										
		2014	**2015**	**2016**	**2017**	**2018**	**2023**	**2028**	**2033**	**2038**
(+)Gross Airport Tariff Revenue		252,65	251,77	269,68	272,21	280,09	336,94	401,67	478,94	569,72
(-) Deductions	14,25%	(36,00)	(35,88)	(38,43)	(38,79)	(39,91)	(48,01)	(57,24)	(68,25)	(81,19)
(=) Net Airport Tariff Revenue		**216,65**	**215,89**	**231,25**	**233,42**	**240,18**	**288,93**	**344,43**	**410,69**	**488,54**
(+) Gross Revenue (Storage and Handling)		156,09	165,00	170,99	179,84	185,83	218,43	254,09	295,60	343,04
(-) Deductions	14,25%	(22,24)	(23,51)	(24,37)	(25,63)	(26,48)	(31,13)	(36,21)	(42,12)	(48,88)
(=) Net Revenue (Storage and Handling)		**133,85**	**141,49**	**146,63**	**154,21**	**159,35**	**187,30**	**217,88**	**253,48**	**294,15**
(+) Non-Tariff Gross Revenue		256,40	271,70	318,40	332,60	355,40	446,60	562,30	694,30	849,60
(-) Deductions	10,15%	(26,15)	(27,71)	(32,48)	(33,93)	(36,25)	(45,55)	(57,35)	(70,82)	(86,66)
(=) Non-Tariff Net Revenue		**230,25**	**243,99**	**285,92**	**298,67**	**319,15**	**401,05**	**504,95**	**623,48**	**762,94**
NET REVENUE		**580,74**	**601,37**	**663,80**	**686,30**	**718,68**	**877,27**	**1.067,25**	**1.287,65**	**1.545,63**
(-)OPEX		**(317,20)**	**(297,40)**	**(309,90)**	**(285,00)**	**(295,90)**	**(340,10)**	**(428,00)**	**(474,40)**	**(569,10)**
(-) Variable contribution fee	5%	**(33,26)**	**(34,42)**	**(37,95)**	**(39,23)**	**(41,07)**	**(50,10)**	**(60,90)**	**(73,44)**	**(88,12)**
(+) Rebate	9,25%	**15,92**	**14,50**	**14,74**	**13,11**	**13,53**	**14,94**	**17,90**	**18,71**	**21,07**
EBITDA		**246,20**	**284,05**	**330,69**	**375,18**	**395,24**	**502,02**	**596,25**	**758,51**	**909,48**
(-) Depreciation		0,00	(3,60)	(13,80)	(53,60)	(60,80)	(171,70)	(236,80)	(313,30)	(238,40)
EBIT		**246,20**	**280,45**	**316,89**	**321,58**	**334,44**	**330,32**	**359,45**	**445,21**	**671,08**
(-) Imcome Tax	34%	(83,71)	(95,35)	(107,74)	(109,34)	(113,71)	(112,31)	(122,21)	(151,37)	(228,17)
Net profit		**162,49**	**185,10**	**209,15**	**212,25**	**220,73**	**218,01**	**237,24**	**293,84**	**442,91**
(+) Depreciation		0,00	3,60	13,80	53,60	60,80	171,70	236,80	313,30	238,40
(-) CAPEX		(113,20)	(528,20)	(565,50)	(318,80)	(455,20)	(329,20)	(214,30)	(161,80)	(62,18)
(-) Initial Working Capital	4,20%	(27,94)								
(-)ΔChange in Working Capital Need	8,30%		(1,71)	(5,18)	(1,87)	(2,69)	(2,85)	(3,42)	(3,95)	(4,61)
FCF		**21,36**	**(341,22)**	**(347,73)**	**(54,82)**	**(176,36)**	**57,66**	**256,32**	**441,40**	**614,53**