De-Risking Project Finance for Infrastructure Development Through Flexibility in Engineering Design

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ABSTRACT

An approach to de-risking infrastructure projects and increasing their bankability is proposed, where flexible design is used to complement traditional Public-Private Partnerships (PPPs) under Project Finance schemes. By definition, forecasts of future project performance will 'always' be wrong in that actual future demand 10 years after the planning phase almost always differs from the forecasts. The potential divergence between predicted and actual demand becomes crucially important if the project's costs are to be recovered from the revenue stream it is supposed to generate. Whereas traditional financing schemes rely exclusively on contractual terms to reduce risks to lenders, an engineering-based framework to mitigate demand and credit risks is proposed as a complement to current approaches.

This thesis presents in detail how the use of flexibility in engineering design could be implemented to de-risk PPPs and increase their bankability. A strategic planning process that recognizes the uncertainty surrounding future conditions and prepares to accommodate them at the lowest cost is the key to de-risk a project technically. This will provide an effective tool to manage demand risk and fully realize the potential of PPPs while scaling down the need for credit enhancements. Projects with lower value at risk and larger upside potential can maximize finance for development and consolidate much needed pipelines of infrastructure projects that close existing infrastructure gaps.

To illustrate the proposed process, the de-risking effect of airline involvement in airport planning and design in the United States is analyzed in detail. Airport projects offer considerable scope for flexible design, as passenger buildings and many other airport facilities can easily be designed and implemented in modules. By completely transferring demand and credit risks to airlines, the financing of airport developments in the United States has overall managed to avoid significant financial project risks. Important lessons can be learned from this interesting model to mitigate demand and credit risks in infrastructure investments.

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To my sisters for filling the gaps and showing me what smart really means.

To the friends that have made this journey even more enjoyable and remarkable.

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Chapter 1

INTRODUCTION

Infrastructure development faces a paradox. If the current rate of underinvestment is maintained, the world will fall short by 350 billion a year of much needed infrastructure projects to support expected economic growth (McKinsey & Company, 2016). If the UN Sustainable Development Goals are considered, this figure roughly triples with a high concentration of needs in developing countries. Simultaneously, there is abundant private-sector interest in the return profile of infrastructure assets. Many institutional investors, with over 100 trillion in assets under management as estimated by the International Monetary Fund, have significantly higher infrastructure investment allocation targets than current holdings. However, countries' infrastructure needs are largely unmet. Why do planners fail to mobilize available capital to bridge an ever-increasing infrastructure gap?

A predictable pipeline of well-structured projects is often recognized as one of the biggest hurdles. Investments in large infrastructure projects are considered risky, as it is common that they fail to provide adequate financial returns and generate the expected economic benefits. As a consequence, and given the magnitude of resources required for infrastructure projects, investors are unwilling to commit large sums unless significant security is provided against project risks. Many strategies are used to address uncertainty, bring feasibility to projects, and mitigate risks for lenders. Unfortunately, results are meager.

This document argues that while current approaches focus on a range of contractual procedures to de-risk projects from the lenders' perspective, nothing is done about their technical design. However, there are great opportunities in that regard. As the debt and equity used to finance a project are paid back from the cash flows it generates, drastic deviations from the forecast streams of revenue have the potential of bringing financial distress, bankruptcy, and governmental bailouts. As a complement to traditional mechanisms used to address uncertainty in project finance structures, this thesis proposes the use of flexibility in engineering design to improve a project's risk profile and exploit the opportunities that uncertainty provides.

Technically de-risked projects should be easier to finance, hence increasing the number of feasible projects that are executed. By embedding real options in the engineering design of an infrastructure

project, financial analyses show a higher expected value, lower capital expenditure at the outset, and a lower value-at-risk. Technical flexibility is the main tool that managers have to face demand risk as it allows them to shape their system to accommodate future conditions and requirements at the lowest cost. Projects with higher expected values and lower risks will mobilize private sector financing at higher proportions in the light of vast infrastructure gaps.

Chapter 2

PUBLIC-PRIVATE PARTNERSHIPS AND PROJECT FINANCE IN INFRASTRUCTURE PROVISION

2.1 Introduction

Development economists have considered physical infrastructure[1] to be a precondition for industrialization and economic development as it improves the long-term production and income levels of an economy (World Bank Group, 2014). Furthermore, it has been shown that infrastructure development is one of the essential components of poverty reduction as it fosters the adequate conditions for progress in competitiveness and the expansion of a country's productive systems (Grimsey and Lewis, 2004).

In developing countries, the lag in transportation infrastructure has been recognized as one of the most important constraints to economic growth and, in turn, one of the main challenges in competitiveness (Farquharson *et al.*, 2011). As a consequence, governments try to devise comprehensive investment programs to reduce the existing infrastructure gap and consolidate national transportation networks through a continuous and efficient connectivity between nodes. Countercyclical policies based on infrastructure provision exhibit positive social and economic cost-benefit ratios that confirm the relevance and high impact of the planned investments (Grout, 1997).

Engel, Fischer and Galetovic (2014) identify four main challenges that governments face when providing infrastructure services: 1) project selection – an adequate plan and a procedure that guarantees that feasible projects are pursued; 2) verification of the fulfillment of the project's service obligations, beyond technical requirements; 3) ensuring that the charging scheme is fair for

[1] Infrastructure encompasses the basic facilities and services that are necessary for a nation's development. Infrastructure can be further subdivided in two categories: economic infrastructure, that deals with the assets and services required for economic development (including transportation, energy, water and sanitation, solid waste, and related services); and social infrastructure, that is centered on human development and includes services related to healthcare, education, prisons, and governmental operations.

both the public and the government; and 4) financing the investment, whether it is through direct public budget allocation or through private sources.

This chapter will focus on the fourth challenge: the financing of investments in large, long-term infrastructure projects. Initially, the many options that exist to provide the public services derived from infrastructure assets will be exposed. Given the recent solid trend towards Public Private Partnerships, lending for PPPs using Project Finance borrowing will be analyzed as well as how it creates a structure to face long-term uncertainties regarding project performance. Considerable resources will be devoted by sponsors to reduce and adequately manage uncertainty and align disparate motivations and interests. Despite these efforts, PPPs have a challenging risk management issue. The magnitude of the issue, the ways in which it has been addressed, and an innovative approach to dealing with it will be presented in subsequent chapters.

2.2 Infrastructure Provision Methods

There are numerous ways of facing providing public infrastructure services and the literature has condensed them in three main models: public provision, Public-Private Partnerships (PPPs), and privatization. As its name suggests, PPPs lie in the space within the purely public and the purely private models, with different shades that range from mixed companies to concession, leases, or management contracts.

A broad range of ownership and operating models exist that can help government advance their objectives without totally relinquishing control (refer to Figure 1). Additionally, it is important to mention that there is no one-size-fits-all model that can be established in every infrastructure project. Macroeconomic conditions, governmental objectives, and financial and economic considerations will shape the peculiarities of a successful model.

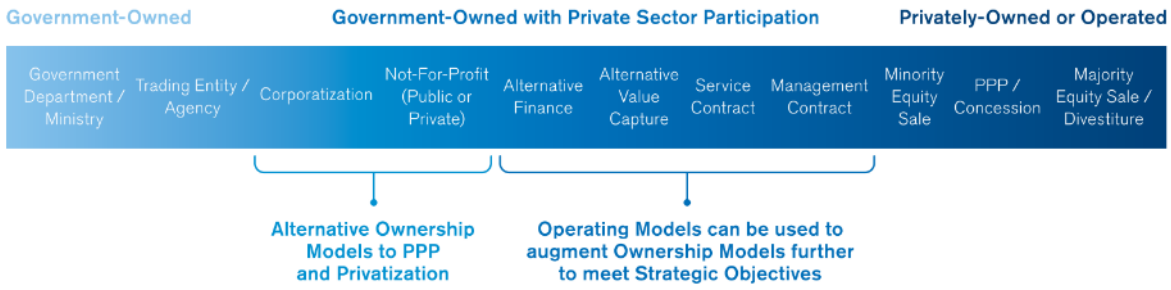

Figure 1 Alternative Ownership and Operating Models (IATA, 2018)

The main models identified in Figure 1 are:

Government Department or Ministry/Agency:
The government owns and manages the infrastructure, generally through a ministry or associated entity. A positive aspect of this model is that the government maintains control of a strategic asset. From the negative point of view, investments in these assets normally respond to political cycles, rather than to technical or financial reasons.

Corporatization:
An independent entity is created and given the responsibility of planning the development of the infrastructure and running its operations. A private corporation-like management model is used to increase the efficiency of the operations.

Not-for-Profit:
The non-profit model is used in some regional or community infrastructures that provide vital services for specific populations. This model does not pursue profit: all profits are re-invested in the infrastructure itself.

Service Contract:
This is a form in which an infrastructure that is owned by the government contracts services from the private sector. Examples in the airport sphere are luggage handling, snow removal, and security among others.

Management Contract:
While maintaining the ownership of the assets, the government can contract the management of the day-to-day operations. This a way of tapping into private sector efficiencies but the effectiveness of the arrangements depends on how clearly the boundaries are defined between both parties.

Public-Private Partnership (PPP)/Concession:
Concession contracts or PPPs merge some of the characteristics just mentioned in a long-term contract where a private special purpose vehicle is responsible for the planning, finance, construction, operation, and maintenance of an infrastructure. In it, risks are allocated to the party in best shape to handle, mitigate, or absorb them. A key characteristic of PPPs is that governments pay for the provision of a service and not the construction of an asset. This document will focus on infrastructure provision through PPPs.

Majority Equity Sale/Divestiture:
The control of the asset is transferred completely to the private sector. As most infrastructure assets exhibit characteristics of natural monopolies, these sorts of transactions are usually accompanied by the development of industry-specific regulations and a regulatory body.

Regulating Private Participation

Gómez-Ibáñez (2003) identifies diverse shortcomings of external regulation of infrastructure: problems with asymmetric information, short-run cost containment, possibility of regulatory capture, long-run investment incentives, and regulatory opportunism. These circumstances might lead to prices that are above marginal cost, create inefficiencies, and increase the dead weight loss that society faces. A way of replacing the role of the regulator is through regulation by contracts, where different bidders compete for the 'franchise'.

In general terms, a regulatory contract sets the rights and obligations of the counterparties, distributes the identified risks, and defines the incentives and responsibilities under which a given public service will be provided for (Klein, 1998). According to Viscusi, Harrington and Vernon (2005), regulation by contract provides additional benefits in comparison with privatization: the fact that the public sector does not require detailed information about costs, demand, and other features of the projects, reduces the need for a traditional regulatory agency which can closely regulate them. In the case of regulatory contracts, a solid institutional framework becomes very important due to the long-term contractual relationship between the counterparties. Inadequate institutions provide a fertile ground for expropriation and regulatory taking by the government as well as opportunistic behavior by the concessionaire (Cruz and Marques, 2013).

2.3 Selection of Provision Model

Given the wide spectrum of possibilities for public infrastructure provision, it is necessary to define which option is the best suited for each particular case. A Value for Money (VfM) analysis compares the potential benefits and costs of delivering infrastructure services through a PPP in comparison with traditional public procurement (World Bank Group, 2017). Often referred to as the Public-Sector Comparator (PSC), the VfM analysis seeks to calculate the cost for the government of bearing project risks under each alternative and can be approached in quantitative and qualitative ways. This exercise is an important part of a PPP structuring process as it thoroughly examines the proposed risk allocation scheme.

For a project to be pursued as a PPP, the benefits derived from efficiency and private innovation must outweigh the premium that the private sector will charge for managing the risks that the government transfers – risks retained by the government are not considered as they should be the same regardless of the provision method (World Bank Group, 2013). There are various methodologies for quantifying the cost of bearing risks (Boussabaine, 2014) and there is important discrepancy regarding the type of assumptions that support them: cost and revenue, efficiency gains, private innovation, use of discount rates (whether it should be the same for both alternatives,

given that the risk profile is different), historical information, financial modelling, probability distributions, and others.

Due to the fact that many PPP programs have a limited availability of information to serve as basis for the quantitative analysis, a qualitative approach based on expert judgement is not uncommon. Despite the value that both the quantitative and qualitative analyses can bring to inform decision-making, they "should be understood and communicated more as a tool to consistently and systematically assess the combined result of a set of assumptions, than as a scientific process that provides 'proof' of VfM" (World Bank Group, 2013).

2.4 Public-Private Partnerships

Even though there is no internationally accepted definition of Public-Private Partnerships (PPP) and different jurisdictions use varied nomenclatures to describe similar projects, transversal elements exist among PPP interpretations. Therefore, the term PPP encompasses as many different definitions as there are projects, and generalizations must be handled with care. The InterAmerican Development Bank defines a PPP as a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance (Interamerican Development Bank, 2014).

Some key advantages of PPPs stem out of this definition. The fact that under a PPP the public sector pays for the provision of a service and not the delivery of an asset implies that the profile of payments is substantially different (spread over the long-term rather that concentrated in the short-term), the contract is focused on outputs (such as road surface quality) and not on inputs (such as road surfacing materials and design), the way to measure the product is different (key performance indicators are measured where the quality of the service is scrutinized, not the way or means to provide the service) as well as how the product is delivered. As the private sector's retribution is defined by the quality of the service it provides, innovation and a life-cycle approach are encouraged.

The characteristic duration of PPP arrangements implies that many components and risks can arise from such a long-term contractual relationship and change dynamically over the PPP's life-cycle. By nature, PPP contracts are incomplete given the impossibility of redacting a contractual consequence for any and every event that might occur in the duration of the partnership. Therefore, the risk distribution in a PPP is essential to guarantee the economic equilibrium of the contract and define responsibilities according to who is in best condition to manage, absorb, or mitigate the risk.

Usually, PPPs involve the bundling of the design, construction, management, and operating phases of an infrastructure project with the purpose of aligning the best practices in each phase and

reducing life-cycle costs. It is common that the public sector relinquishes some control over the infrastructure by assigning these tasks to the private sector as a way of levering on the latter's efficiencies.

The transfer and sharing of responsibilities and risks to the private party means that the government must develop a regulatory framework to: 1) bring confidence to the private sector that the rules under which the contract was drafted will be maintained; and 2) assure that there will be effective supervision and oversight of the project to guarantee that the social and economic benefits of it are delivered (Engel, Fischer and Galetovic, 2014). This is why countries must develop policies, laws, regulations, institutions, and capacity needed for both parties to benefit fully from PPP arrangements and to encourage private investment (PPIAF, 2018).

PPPs can be more expensive than public procurement: the Special Purpose Vehicle (SPV) created for the project usually has access to higher financing rates than a national government (as the collateral is the project and not any real asset, and the probability of default for a government is much lower) and the risk bearing by the private party comes with a price (usually reflected in the discount rate used and therefore in the amount of revenues required to offset the initial outlays). Additionally, a weak framework can lead to unjustified private gains (due to the possibility of opportunistic bidding and renegotiations) and a wanting prior planning that leads to poor performance can lead to an unexpected increase in the contingent liabilities that the government must respond for. Nevertheless, if the process and the project are structured in the correct way, the efficiency gains that the involvement of the private sector brings will more than offset the additional costs.

Multilateral agencies such as the World Bank, the International Finance Corporation (IFC), the Global Infrastructure Facility, the InterAmerican Development Bank and IDB Invest, among others, have been assisting national governments in the quest for infrastructure development. The results yielded in the legal and financial structuring of PPP contracts have created a reputation of being "honest brokers"[2] with a strong focus on fairness and sustainability (Esty, 2003). In addition, these institutions usually approach finance differently, by accepting subordinate loans with longer maturities and lower financial rates of return – if the economic rates are appropriate. They also act as a deterrent for opportunistic behavior and corrupt actions in PPP deals: their international nature implies a higher scrutiny by experts with different backgrounds and greater consequences in the international scenario for governments performing unilateral, arbitrary modifications. Finally, the added value of multilateral development agencies' involvement in infrastructure projects supports the attainment of private financing, which is well seen by rating agencies due to the guarantees that they provide (either liquid or related to the process).

[2]The defining characteristic of the honest broker is a desire to clarify, or sometimes to expand, the scope of options available for action so as to empower the decision maker. An honest broker is characterized for its independent and unbiased advise (Pielke, 2007).

2.5 Project Finance Borrowing

It is common that large infrastructure projects, given their complexity and long-life cycles, are managed by an entity devoted entirely to such purpose. As mentioned previously, when a project's costs are to be recovered from the revenue stream it is supposed to generate, the project is its own collateral. Project Finance, as opposed to Corporate Finance, is the financing technique where the repayment of the project loan is limited to a great extent by the revenue generating capacity of the assets being financed. This document will refer to PPPs that are financed through Project Finance schemes, given their size and complexity. The alternative to Project Finance in infrastructure provision -- i.e. the Corporate Finance structure -- is traditional public procurement where a government's balance sheet provides security for lenders.

The definition just presented suggests that there is no recourse beyond the value of the project's assets. This is precisely the distinction with Corporate Finance techniques: recourse in Project Finance is limited to a clearly defined set of assets, while in Corporate Finance structures lenders have recourse to all of the borrowers' assets. However, non-recourse finance is rare and in most cases there is some limited recourse to the sponsors in the form of guarantees (Dentons, 2013). The structure and effects of guarantees in project finance borrowing will be discussed in greater detail in Section 4.2.2. The terms "non-recourse finance" and "limited recourse finance" will be used interchangeably with the term "project finance" in this document.

There are many reasons to use a Project Finance structure for large engineering projects, despite the facts that it is more expensive than traditional Corporate Finance and it requires a higher amount of resources in terms of time, effort, and expertise to do so successfully. The following list presents some arguments in favor of Project Finance borrowing (Esty and Sesia, 2004):

- **Control of Collateral:** The contractual and financial structure of the deal results in exclusive access to the project's collateral in the form of repayments from asset liquidation or for negotiation purposes with other parties.
- **Active Sponsors:** Project size requires involving partners with very specific expertise and financial muscle to handle the complexity of the project over its life-cycle. Equity contributions from sponsors aligns their incentives to facilitate project success.
- **Covenant Triggers:** Step-in rights and covenant triggers serve as "early warnings" for banks to renegotiate before the project's credit quality deteriorates beyond a curable point. This feature is not exclusive of Project Finance structures, but its higher restrictions in comparison to Corporate Finance trigger earlier renegotiations.
- **Restrictions:** The use of proceeds is clearly determined with the purpose of reducing risk to lenders, sometimes deferring dividend disbursement until debt has been serviced fully.

- **Cash Flow Protections:** Offshore and debt service reserve accounts are included to reduce the impact of temporary revenue shortfalls.
- **Debt Limits:** Raising additional debt is prohibited, resulting in higher debt service coverage ratios due to diminishing liabilities and steady or increasing revenue.
- **Transparency:** Higher transparency of the planning process and the project's performance due to its stand-alone nature. As the project is its own collateral, its capacity to generate revenue will be closely scrutinized.
- **Loan Syndication:** The possibility of syndicating loans allows the sponsors to tap to different market segments with disparate appetites for risk, under a clearly defined structure of seniority.

The items presented in the previous list contribute to achieving very favorable probabilities of default (PD) and losses given default (LGD) when compared to Corporate Finance borrowing. According to a report of Moody's Investors Service that analyzes the Default and Recovery Rates for Project Finance Bank Loans between 1983 and 2015: the 10-year cumulative default rate for project finance bank loans is 6.7%, where marginal annual default rates are consistent with marginal default rates of high speculative-grade (risky) loans in the first three years. However, they trend towards marginal default rates that are consistent with single A category corporate ratings by year seven from financial close. Ultimate recovery rates for project finance bank loans average 79.5%. However, the most likely ultimate recovery rate is 100% meaning that there is no economic loss (Moody's Investor Service, 2017).

An essential feature of Project Finance structures that facilitates the limitation of liability for sponsors is the Special Purpose Vehicle (SPV) or project company that is constituted for the sole purpose of conducting business associated to the project. The SPV will bid for the project and, if successful, will become the concessionaire with all the obligations derived from such position. The SPV will then be the borrower in the Project Finance deal without additional assets beyond the ones contemplated in the scope of the project. As a result, what the SPV can and cannot do is clearly defined at the outset with the purpose of providing comfort to lenders that their money will be used appropriately. The engagement of the SPV in activities different from those related to the infrastructure project subject of the concession contract is prohibited, providing greater transparency and reducing possible agency conflicts. The SPV will be a party to a series of contracts that will enable the provision of the contracted service. These might include essential activities such as the design, construction, operation, purchase of project's inputs, and sale of its inputs.

The features just described have several positive consequences. They introduce distance between the project and the sponsors that can be used to mitigate political and credit risk. As a financing mechanism, the details of debt service can be tailored to the specificities of each project, which can be more complicated in corporate finance. As lenders have no recourse beyond the project's assets, early warning systems are built in the agreement to promote easier renegotiations. However, it is a fragile structure that relies largely on a series of contracts for support and risk allocation. As a

consequence, the costs of asymmetric information, agency conflicts, financial distress, and (in some cases) corporate taxes can be reduced, despite the higher costs of transaction (Bodmer, 2015).

2.6 Sponsors in Infrastructure Project Finance Deals

A broad definition of sponsors will be used in this document, as those persons (natural or legal) that have an interest in promoting an infrastructure project. Usually, this interest implies a stake in the outcomes of the project whether it is through debt and equity contributions or as a guarantor of some contingent event. Sponsors are active stakeholders that use their expertise and capital to advance the project's objectives. As the nature of the activities that have to be performed by the SPV is highly varied and cross-disciplinary -- engineering, financial, legal, social, and environmental requirements, among others -- sponsors in an infrastructure project can have a very diverse background. Further analysis will be devoted to public and private sponsors in particular.

2.6.1 Public Entities

Given the public nature of the services provided by infrastructure projects, the involvement of governmental agencies, ministries or institutions is prevalent. Public participation will therefore range from simply providing the consents and permits required for the private party to undertake the project to actively supporting its development by different means -- including credit enhancement measures and sovereign guarantees against political and demand risk. As most governments are interested in promoting direct foreign investment and infrastructure development due to their positive economic externalities, private parties regularly find in their public counterparty a willingness to engage.

However, the magnitude of resources involved and high-visibility of infrastructure projects makes their planning process susceptible to political capture. The mismatch between a project life-cycle (20-50 years) and political cycles (4-10 years) exacerbates the risk of a wrongful and inefficient selection of projects. Incentives against it can be introduced by the participation of a diverse group of stakeholders, such as Multilateral Agencies, Export Credit Agencies, and independent experts.

The allocation of risks is a delicate matter for government officials, which strive to reach an equilibrium where the private sector obtains a fair return for the risks that it assumes. The public will judge harshly any rents that the concessionaire obtains as well as projects that face financial distress, bankruptcy, or bailouts, which is why officials face a complex negotiation process. As a result, the officials involved in the details of project structuring will be risk averse due to concerns of peculation-related prosecution.

2.6.1.1 Multilateral and Export Credit Agencies

Multilateral Agencies (MAs) such as the World Bank (WB), the International Finance Corporation (IFC), the European Investment Bank (EIB), and the African, Asian and InterAmerican Development Banks (AfDB, ADB, and IDB, respectively) enhance the bankability of infrastructure deals by providing protection against specific risks that the project might be exposed to. In particular, the effects of political risk in what concerns to exchange rates, interest rates, and failure to fulfill agreed payments are targeted by MAs.

As a result, the involvement of a MA can attract financial institutions and other providers of private funding to a project that would otherwise be considered unfeasible. The participation of this type of agencies is additionally sought by private sponsors due to the deterrence effect that it has on host governments: a government that fails to honor its obligations with a MA will not be eligible for further support in the future.

Export Credit Agencies (ECAs) are national entities that provide financial support for the purchase of certain goods originated in the ECA's country of origin. The involvement of these agencies can have a series of advantages for a project's perceived financial return: they are willing to provide insurance against political risk, longer repayment periods than commercial financial institutions, and access to lower interest rates when loans are backed by the ECA's country of origin credit rating (Dentons, 2013).

2.6.2 Private Parties

2.6.2.1 Debt Providers

The vast amounts of resources required for infrastructure projects limits the number of financial institutions capable of providing them. As a result, it is common that syndicates of lenders are created with the objective of gathering the necessary expertise and capital to analyze and fund such complex transactions. Within the syndicate, finding a clearly defined seniority is common as a function of a financial institution's expertise, capital, and risk appetite.

As lenders have limited or no recourse against borrowers' assets in project finance structures beyond the SPV's assets, they will require a much more elaborate process and complex contractual architecture to reduce the risk of default. Very tight covenants, warranties, and events of default will be defined and serve as early warnings of deteriorating performance. It is also common that guarantees are provided by host governments or multilateral agencies to facilitate the bankability of deals. Despite their existence, lenders will appoint independent engineers to monitor project execution and performance.

2.6.2.2 Equity Providers

Equity providers are less risk averse than debt providers, given their position in the waterfall of repayments and their entitlement to the project's upside. In PPPs, private sponsors with a vested interest in the success of the project are usually involved as shareholders. As mentioned previously, their background can be very varied with one common characteristic: they provide key expertise that will be essential to achieve positive project outcomes.

It is common that key stakeholders of the PPP's life-cycle participate also as equity providers -- i.e. the construction, operating, and structuring firms. These companies have the incentives to create a successful project, as the fees that they charge for the services provided to the SPV can be low in comparison with the project's potential upside. These companies are willing to take more risk than lenders as they rely on their expertise to face it.

Some PPP frameworks require direct participation from project sponsors in the form of equity with the purpose of them having "skin in the game", hence reducing agency problems. However, a poorly-designed scheme of sovereign guarantees may numb the incentives that these sponsors have to efficiently face uncertainty.

2.6.2.3 Independent Experts

The technical challenges that large infrastructure projects often face leads sponsors to involve independent experts over the life-cycle of the project. Different consulting firms and expert advisors will be involved during the planning phase (e.g. demand forecasters, specialized designers contracted by the SPV) and the implementation phase (e.g. independent engineer appointed by the lenders, government, MAs and/or ECAs) to monitor and verify the due diligence of the parties. As the access of the SPV to revenue is generally conditioned to the approval of a third independent party, the transparency of the process is augmented in favor of the financial and economic objectives of the infrastructure project.

2.7 Conclusion

The limited or no recourse feature of infrastructure project finance implies that the bankability of a project is determined by the lenders' perception of how much can the revenue-generating capacity of the project fluctuate. A lot of resources are devoted to forecasting future demand and revenue, but how effective are they? How uncertain are infrastructure projects? Next chapter attempts to answer these questions.

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Chapter 3

UNCERTAINTY IN INFRASTRUCTURE PUBLIC PRIVATE PARTNERSHIPS

3.1 Introduction

Large infrastructure investments are highly uncertain projects in terms of demand, capital costs, and benefits (Cruz and Marques, 2013). This is caused by macroeconomic fluctuations, market variations, political factors, and technological shifts over long time periods that are nearly impossible to predict with total certainty.

The potential economic and financial returns of an infrastructure project, as seen during the bidding phase, depend on the risk each bidder is willing to take. As a result, the bidder with the highest appetite for risk often wins the concession by being more optimistic. It seems then that the traditional bidding process for large infrastructure projects has a perverse incentive for bidders to overestimate benefits and underestimate costs.

Discarding arguments of corruption, collusion, and incompetent institutions, reasonable or underestimated costs and benefits can be wrong: the future is uncertain and rare, high-impact events can materialize. The vulnerability of infrastructure projects to long-term uncertainties has the potential of materializing the opposite expected effects of the investment, including accumulation of debt and non-performing loans, distortionary monetary expansion, economic underperformance and instability, and lost alternative investment opportunities (Ansar *et al.*, 2016).

This chapter will present how uncertain infrastructure projects are, based on the difference between the expected and actual results. It will argue that this discrepancy is derived from attempting to define future conditions that result in significant risks for the parties involved. When the future unveils in an unexpected (and not favorable) way, unmet obligations, financial distress, bankruptcies, and governmental bailouts are frequent. Recognizing that the future is uncertain and forecasts are 'always' wrong can create a different approach to infrastructure planning.

3.2 How uncertain are infrastructure projects?

Empirical evidence suggests that deviations from forecast demand in large infrastructure projects are frequent. Flyvbjerg, Holm and Buhl (2005), analyzed 210 projects (27 rail and 183 road) in 14 nations and concluded that there is no clear trend towards under or over estimation in road projects, simply systematic inaccuracy. Figure 2 presents the distribution of results, where the performance of traffic ranges between 20 and 170% of the forecast values. In this case, the average inaccuracy is 9.5% with a standard deviation of 44.3%. In rail projects, however, there seems to be a systematic over estimation of demand: Figure 3 shows the distribution of results, ranging between 10 and 160% of forecast traffic with and average inaccuracy of 51.4% and a standard deviation of 28.1%. The authors invoke strategic misrepresentation as the cause for such a clear over estimation of demand in rail projects.

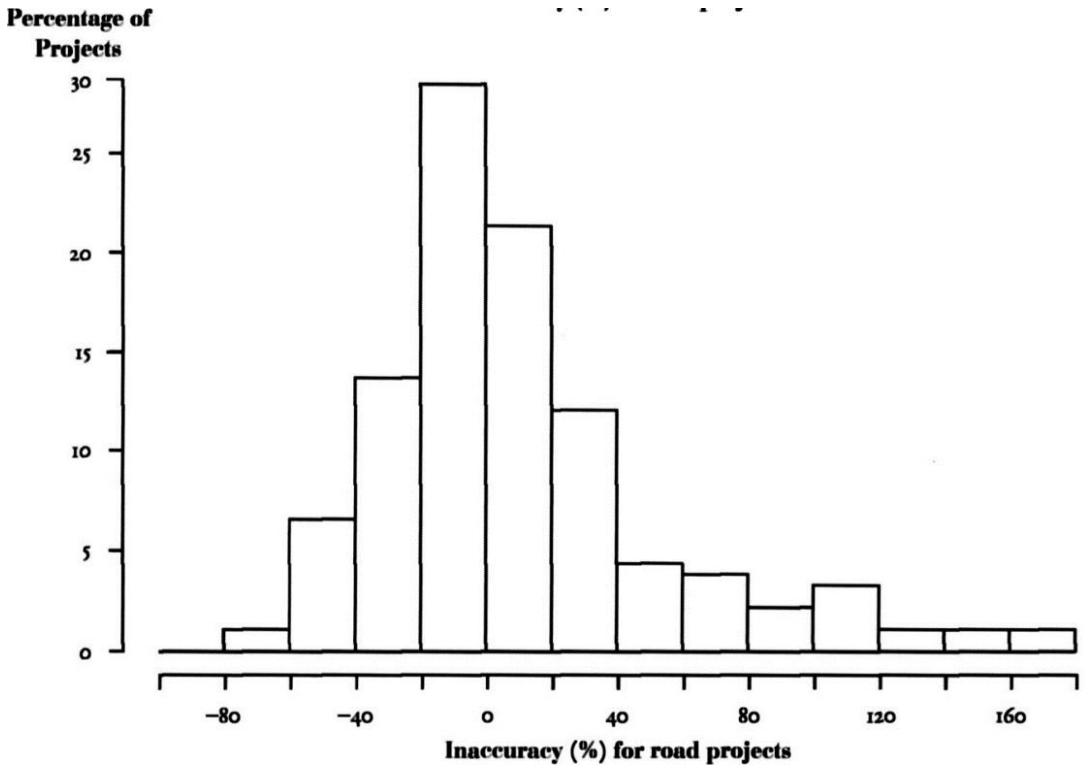

Figure 2 Forecast performance distribution for 183 toll road projects (Flyvbjerg, Holm and Buhl, 2005)

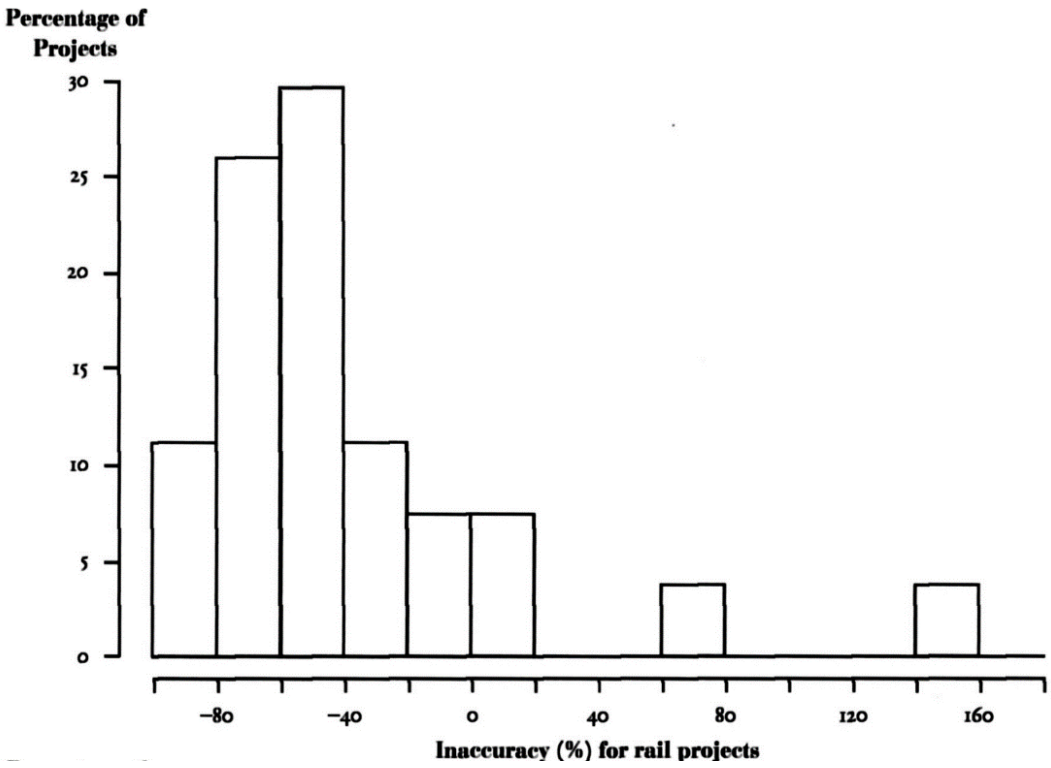

Figure 3 Forecast performance distribution for 27 railroad projects (Flyvbjerg, Holm and Buhl, 2005)

Assumptions that do not materialize are identified as the main driver behind the inaccuracy of traffic forecasts. Whenever land use, time savings, willingness-to-pay, improvements to competitive routes, severity and duration of the ramp-up phase, macro-economic, and traffic composition assumptions changed from those assumed by traffic forecasters, the divergence between actual and forecast traffic is expected to accentuate. In many cases, recessions or economic downturns were considered as the underlying reason for the deviations, given the correlation between economic growth and traffic growth.

Bain (2009) addressed this subject in a database of predicted and actual traffic usage for over 100 international, privately financed toll road projects, concluding that the range of inaccuracies is often large with a tendency towards over estimation. Figure 4 presents the distribution of the ratio between actual and forecast traffic for the first year of performance in 104 toll road projects. As the distribution is not centered on 1.0 (mean equals to 0.77), a trend towards over estimation of demand can be identified in the first year of project operation in comparison to the forecasts used to achieve financial close. Actual/forecast ratios that range between 0.15 and 1.50, imply that on one extreme of the range actual traffic was 15% of the forecast one in the opening year, while in the other one it equated to an extra 50%. This error range illustrates the possible magnitude of uncertainty in demand forecasts for road infrastructure projects.

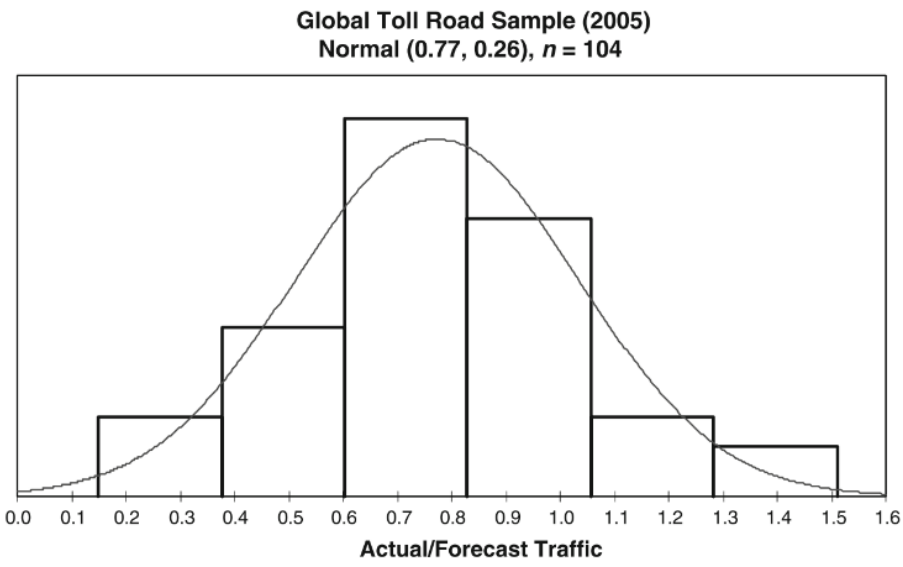

Figure 4 Forecast performance distribution for 104 toll road projects (Bain, 2009)

Bain also includes an interesting effect of the sensitivity of traffic forecasts to different sets of assumptions. Figure 5 shows four base-case forecasts for a toll road conducted by internationally recognized traffic and revenue consultants within months of each other. The same project structured under each vector will produce very different results in terms of expected traffic, revenue, physical infrastructure requirements, benefits to society, and returns to investors. Bain suggests that financial engineers need to ensure that the project structures remain flexible and retain liquidity so that the effects of these (very probable) deviations from the expected project performance can be handled without devastating effects.

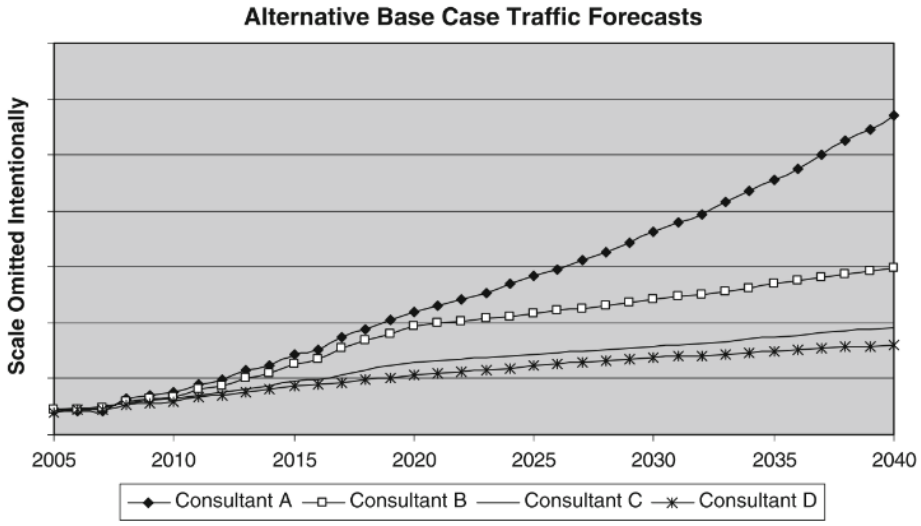

Figure 5 Base case traffic forecasts conducted by four different traffic and revenue consultants (Bain, 2009).

Traffic forecasting accuracy has not improved over time (Flyvbjerg, Holm and Buhl, 2005). A comparison of the inaccuracy of forecasts over a 30-year period reveals that rail passenger forecasts are as inaccurate in 2005 as they were 30 years earlier, while road activity forecasts have grown more inaccurate. Despite significant advances in data acquisition and modeling capabilities for demand forecasting, assumptions made for the effect of forecasting future conditions are axiomatically wrong.

3.2.1 Demand Risk

Demand risk, understood as the risk that usage of the service is different than was expected, or that revenues are not collected as expected (World Bank Group, 2017) is defined in comparison to a benchmark: the demand forecast. The demand forecast is the variable used to dimension infrastructure projects, define the financing scheme, and determine the expected cash flows that will be available to repay the capital investments. As a result, huge efforts are devoted to obtaining a large enough sample size of historical information that adequately represents past and existing conditions to inform computer-based future demand simulations. Nevertheless, infrastructure planners have not been successful in the task and demand forecasts have proven to be less than accurate and have not improved over time (as was discussed in Section 3.2).

Economic growth, expressed as the percentage change in Gross Domestic Product (GDP) has been found to be positively correlated to demand for infrastructure services (Robinson and Torvik, 2005; Sadka, 2006; Agénor, 2009). The demand elasticities for different infrastructure types will vary, as some infrastructure projects provide essential services whose demand will not be affected by economic downturns. As a result, demand in infrastructure projects is fairly inelastic and will react to changes in macroeconomic conditions. The risk profile of each particular project will determine how demand risk will be allocated (or shared) between project parties. However, when drastic deviations from the expected demand materialize, it is common that *Force Majeure* clauses are invoked, treating the event and its consequences as not preventable nor foreseeable.

3.2.2 Credit Risk

One of the consequences of demand risk, where future demand deviates from the forecast, is credit risk: the potential that the borrower will fail to meet its agreed debt service obligations or default. When the perception of credit risk is high, and given the unequivocal risk-return relationship, banks will impose higher rates on the loans they are willing to offer. To guarantee creditworthiness, many strategies will be employed, and mechanisms introduced in the contracts and the process to mitigate credit risk.

The agreement structure (both contractual and financial) and the planning process are usually where the efforts are concentrated. Additionally, it is frequent that lenders require the introduction of covenants, warrants, and events of default as a way of reducing the probability that credit risk materializes and/or mitigate its consequences. However, as has been shown, too many

characteristics of infrastructure projects based on project finance depend on a forecast of future demand, that most certainly will be wrong.

3.3 Role of Forecasts in Infrastructure Project Finance

In Project Finance deals where project costs are to be recovered from the revenue stream it is supposed to create, the private sector's ability to finance a project is determined by the predictability and reliability of the revenue stream and the traffic forecasts that underpin them (PPIAF and GIF, 2017). The common approach is to build upon a statistically significant historical information to model future growth patterns, with the assumption that the future will perform similarly as the past. However, assumptions by definition are subjective and assuming that past performance is transferable to long-term forecasting is a strong one.

The fact that trends change, surprises occur, and black swan events materialize implies that the accuracy of forecasts diminishes in time. Regardless of the effort devoted in the task of developing projection models that lead to precise demand predictions or specifications, it is important to recognize that forecasts will be wrong to some degree as the future is irremediably uncertain. Forecasts of future activity have a central role in infrastructure PPPs under Project Finance borrowing. As mentioned in Section 2.5, when project's costs (and returns for investors) are to be recovered from its revenue stream, the potential divergence between predicted and actual demand becomes crucially important. Based on the Colombian framework for transportation PPPs, the following characteristics and features of concession contracts are bound to the demand forecast:

- **Project Scope**: the technical specifications of infrastructure projects are defined by an expectation of demand over its timeframe. Based on the concept of economies of scale, it is common that facilities are dimensioned to accommodate peak demands over a PPP contract's duration.
- **Project Duration**: the debt tenor -- and consequently the duration of the project -- is based on the project's revenue generating capacity. As a result, the relationship between a project's revenues and its forecast of activity is essential at determining the details of the credit agreement.
- **Covenants**: covenants based on indicators such as the Loan Life Cover Ratio or the Project Life Cover Ratio are commonly used to review the expected financial performance of a project. As they analyze the ratio of total present value of projected CFADS over the full life of the loan/project to the outstanding debt balance in the period, a forecast of future conditions is necessary. Strong deviations between actual and forecast conditions can mislead business decisions.
- **Sovereign Guarantees**: it is common that sovereign guarantees are offered by countries with a high perception of country-risk as credit enhancement measures. The purpose is to partially guarantee the return on investment. As the capital investment is based on the

expectation of future activity, the forecast has an important role in the sizing of sovereign guarantees.

- **Contributions to Contingency Funds**: in PPPs where demand risk is shared between the public and private parties, contingent liability funds are common with the purpose of accumulating the required capital to face a risk in case it materializes. The contributions are designed to cover the differential between actual and forecast traffic (and revenue) and may be substantial.

Not only the project definition but also its capacity of facing adversity are defined by the exercise of attempting to predict the future. By recognizing that the future is uncertain (not only as optimistic and pessimistic scenarios) and structuring a project with the technical capacity to react to new information, infrastructure delivery can be significantly de-risked.

3.3.1.1 Forecasts are 'Always' Wrong - Example of Energy Prices

This section will analyze the price of the Brent oil barrel as forecasted by GLJ Petroleum Consultants Ltd, an energy resource consulting firm with over 40 years of experience (GLJ Petroleum Consultants, 2019). The yearly extrapolations performed by the firm between 2006 and 2019 will be compared to the actual price of the Brent crude oil barrel in order to appreciate the limitations of the exercise of predicting future conditions. Finally, the result of this exercise will be related to recent infrastructure development efforts in Colombia.

GLJ Petroleum Consultants Ltd presents in its webpage the forecasts for future oil prices as calculated from 2006. The following table presents the forecasted values for each year (black font) and the information used to support the extrapolation (grey font). Additionally, the real values are presented.

Table 1 Brent crude oil barrel forecasts. 2006-2017 (GLJ Petroleum Consultants, 2019)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	REAL
1994	15.82														15.82
1995	17.04														17.04
1996	20.43	20.43	20.31	20.31	20.31		20.31								20.31
1997	19.18	19.18	19.32	19.32	19.32		19.32								19.32
1998	12.83	12.83	13.34	13.34	13.34		13.34								13.34
1999	17.81	17.81	17.99	17.99	17.99		17.99								17.99
2000	28.35	28.35	28.41	28.41	28.41	28.41	28.41	28.41	28.41						28.41
2001	24.37	24.37	24.87	24.87	24.87	24.87	24.87	24.87	24.87						24.87
2002	24.99	24.99	25.02	25.02	25.02	25.02	25.02	25.02	25.02						25.02
2003	28.93	28.93	28.47	28.47	28.47	28.47	28.47	28.47	28.47						28.47
2004	38.20	38.20	38.02	38.02	38.02	38.02	38.02	38.02	38.02						38.02
2005	55.15	55.12	55.14	55.14	55.14	55.14	55.14	55.14	55.14	55.14					55.14
2006	55.50	66.16	66.16	66.16	66.16	66.16	66.16	66.16	66.16	66.16	66.16				66.16
2007	53.50	60.50	72.71	72.71	72.71	72.71	72.71	72.71	72.71	72.71	72.71	72.71			72.71
2008	49.50	58.50	90.50	98.30	98.30	98.30	98.30	98.30	98.30	98.30	98.30	98.30	98.30		98.30
2009	46.50	56.50	86.50	56.00	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50	62.50
2010	45.00	55.50	82.50	66.50	78.50	80.25	80.25	80.25	80.25	80.25	80.25	80.25	80.25	80.25	80.25
2011	43.50	55.50	80.50	72.50	81.50	88.50	110.86	110.86	110.86	110.86	110.86	110.86	110.86	110.86	110.86
2012	43.50	56.00	80.50	83.50	84.50	88.25	105.00	111.71	111.71	111.71	111.71	111.71	111.71	111.71	111.71
2013	44.50	57.00	80.50	90.51	87.50	88.50	105.00	105.00	108.77	108.77	108.77	108.77	108.77	108.77	108.77
2014	45.25	58.25	80.50	92.35	90.50	90.50	102.00	102.50	107.50	99.71	99.71	99.71	99.71	99.71	99.71
2015	46.25	59.50	80.50	94.23	92.34	93.67	100.00	102.50	107.50	67.50	53.60	53.60	53.60	53.60	53.60
2016	47.25	60.75	80.52	96.14	94.22	96.05	100.00	102.50	105.00	82.50	45.00	45.00	45.05	45.05	45.00
2017		62.00	82.16	98.09	96.14	98.76	100.00	100.00	102.50	87.50	54.00	57.00	54.16	54.80	54.80
2018				100.09	98.09	101.24	101.35	100.00	102.50	90.00	61.00	61.00	65.50	71.55	71.55
2019					100.08	103.95	103.38	101.35	102.50	95.00	67.00	66.00	63.50	63.25	
2020						106.06	105.45	103.38	102.50	100.00	73.00	70.00	63.00	68.50	
2021							107.56	105.45	103.38	101.35	78.00	74.00	66.00	71.25	
2022								107.55	105.45	103.38	83.00	77.00	69.00	73.00	
2023									107.56	105.45	88.00	80.00	72.00	75.50	
2024										107.56	91.39	83.00	75.00	78.00	
2025											93.22	86.00	78.00	80.50	
2026												89.64	80.33	83.41	
2027													81.88	85.02	
2028														86.66	

Figure 6 plots simultaneously the different annual forecasts from Table 1. It is interesting to observe the abrupt differences between the forecast and actual prices for the Brent crude oil. In addition, it is possible to detect a tendency in the forecasts. This trend is defined by the model used to extrapolate the historical values and may be correlated to inflation rates.

The limitations of extrapolation models are evident, due to the fact that they do not account for some external factors in the economy and extraordinary events that may seriously affect the forecast variable.

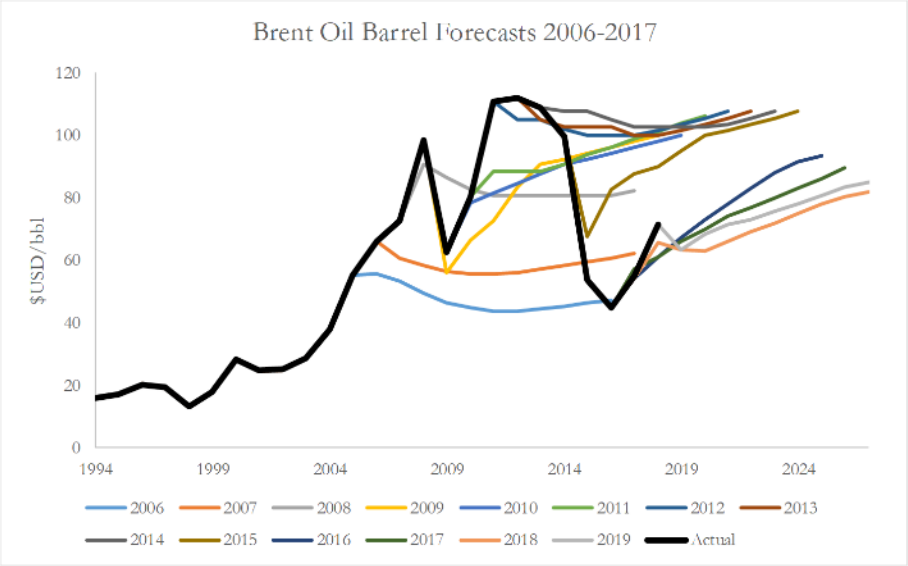

Figure 6 Brent crude oil barrel forecasts. 2006-2017 (GLJ Petroleum Consultants, 2019)

It is desirable to calculate the absolute value of the percent variation between the forecast and observes data. Without discussing the forecasting model particularities, the deviations' magnitudes from actual data render it obsolete. For example, the forecast for 2014 shows 133.33% deviation two years after its publication.

Table 2 Absolute percent variation between forecast and observed values

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2006	16.1%												
2007	26.4%	16.8%											
2008	49.6%	40.5%	7.9%										
2009	25.6%	9.6%	38.4%	10.4%									
2010	43.9%	30.8%	2.8%	17.1%	2.2%								
2011	60.8%	49.9%	27.4%	34.6%	26.5%	20.2%							
2012	61.1%	49.9%	27.9%	25.3%	24.4%	21.0%	6.0%						
2013	59.1%	47.6%	26.0%	16.8%	19.6%	18.6%	3.5%	3.5%					
2014	54.6%	41.6%	19.3%	7.4%	9.2%	9.2%	2.3%	2.8%	7.8%				
2015	13.7%	11.0%	50.2%	75.8%	72.3%	74.8%	86.6%	91.2%	100.6%	25.9%			
2016	5.0%	35.0%	78.9%	113.6%	109.4%	113.4%	122.2%	127.8%	133.3%	83.3%	0.00%		
2017		13.1%	49.9%	79.0%	75.4%	80.2%	82.5%	82.5%	87.0%	59.7%	1.5%	4.0%	
2018				39.9%	37.1%	41.5%	41.6%	39.8%	43.3%	25.8%	14.7%	14.7%	8.5%

Similar forecasts were used by the Colombian government to support the Fourth Generation of Concessions, an ambitious road infrastructure program to reduce the country's infrastructure gap. The Colombian economy is strongly based on oil exportations, which is why its market price defines governmental budgets and expenditure. The unexpected plummet of oil prices experienced in 2014 (~60% drop) and the consequential rise of the Colombian Peso (COP) to United States Dollar (USD) exchange rate (~88% increase), deaccelerated the country's economy and had an

important impact on traffic levels. The next figure presents the behavior of the price of the Brent crude oil barrel and the COP/USD exchange rate 3 years before and after the events of 2014.

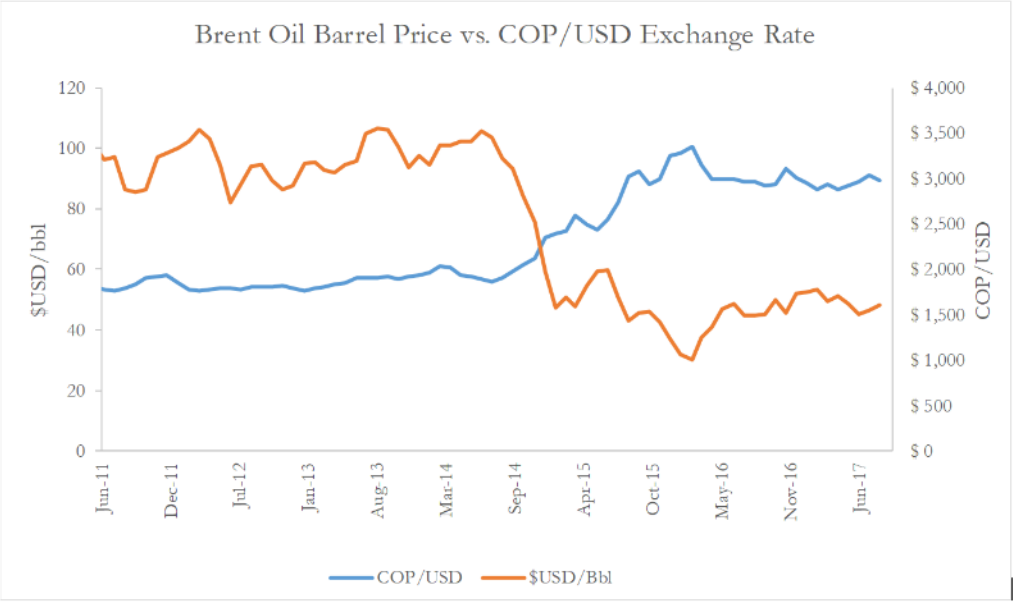

Figure 7 Brent crude oil barrel price (GLJ Petroleum Consultants, 2019) vs COP/USD exchange rate (Banco de la República de Colombia, 2017)

The data analyzed is a good example of forecasting difficulties and the high volatility and uncertainty associated to oil prices. Projects that are based on rigid assumptions will have important issues in case of any deviation from the expected. It is therefore convenient to use strategies during the design phase of the project that will allow a better response to uncertainty.

3.4 Discussion

As forecasts are most likely to be wrong, in the sense that actual future conditions and demand 10 or 20 years after the planning phase almost always differ from the expectation, they cannot be taken as an indisputable truth. Forecasts must be understood as the most-likely scenario given the experts' understanding of past and current events, their expectations about how the future will unveil given their expertise, education, and optimism.

Forecasts should be used to inform the process but treated with skepticism. They are necessary to assess the potential socio-economic benefits of projects, design facilities, and determine their revenue-generating capacity, among others. The key concept here is "potential", as their attainment is contingent on the materialization of all the assumptions made in the forecasting exercise.

Rather than passively hoping for the right conditions to come, the management of a project must proactively seek these benefits by adjusting operations as new information becomes available. It is therefore in the parties' best interest to structure the partnership in such a way that active management is incentivized. However, the presence of guarantees on certain risks numbs the incentives for efficient sizing and management of assets.

The fields of data science and machine learning have interesting contributions to infrastructure planning. As datasets increase in size as well as our capacity of analyzing them, insights and trends that were previously undetected can be understood and acted upon. Nevertheless, there is an indisputable fact: the future does not behave exactly like the past and the conditions in which infrastructure systems will perform are constantly changing (markets, demographics, technologies, and politics are dynamic, break trends, and lead to unexpected results).

As the British philosopher of science Sir Karl Popper states in his work *The Poverty of Historicism* (1957): it is not possible to predict, by rational or scientific methods, the future growth of human knowledge. As the course of human history is strongly influenced by the growth of human knowledge, it is not possible to predict the future course of human history. This means that the possibility of a theoretical history must be rejected; that is to say, of a historical social science that would correspond to theoretical physics. As a result, there can be no scientific theory of historical development serving as a basis for historical prediction.

3.5 Conclusion

Infrastructure projects are subject to vast uncertainties that derive from the dynamic environment in which they perform. These uncertainties materialize as potential divergence between predicted and actual demand (also known as demand risk). When a project's costs are to be recovered from the revenue stream it was supposed to generate, these uncertainties become crucially important. Demand risk translates then into credit risk, which can seriously hinder the bankability of much needed infrastructure development. Practitioners of project finance and infrastructure planners are aware of this fact and have created a series of contractual and financial mechanisms to deal with it. The following chapter will analyze them in detail.

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Chapter 4

CURRENT APPROACHES TO CREDIT RISK MANAGEMENT

4.1 Introduction

Given the dramatic effects that unsuccessful infrastructure projects can have on a country's development, governmental budget, and sponsors' capitals, considerable efforts are made to address risk in Public Private Partnerships. Existing approaches try to provide security for lenders while creating incentives that align the interests of agent and principal. Measures range from creating a contractual structure where the duties and obligations of the different parties are properly defined, as well as how risks are distributed among them; to the planning process, with the expectation of creating better performing projects. When these measures are not sufficient to produce a bankable project that is acceptable for financial institutions, credit enhancement measures are introduced to guarantee and maintain a project's creditworthiness over its lifetime. This chapter will explore these concepts and argue that while they might provide a sense of security to sponsors, they miss important opportunities to proactively manage risk.

4.2 Deal Structure

The structure of a Public-Private Partnership defines how the project's risks, duties, and obligations are distributed among parties. The definition of a concession agreement's structure is done at the outset of the partnership and is clearly and thoroughly stipulated in a contract. The purpose is, among others, to create the incentives for the different parties to efficiently manage risks and lead the project to success. This section will explore how the risk allocation, capital structure, and contractual setup of a deal define the responsibilities of the parties involved, first between the public and private party and then within the SPV. It will serve to show how the setup of the agreement is a very important risk management mechanism.

4.2.1 Risk Allocation

PPPs are regulated through long-term contracts that define the relationship between the parties, their rights and responsibilities, the risks that they will bear, and the mechanisms that might be used to restore any financial disequilibrium caused by materialized risks (World Bank Group, 2017). Explicit, complete contracts provide a clear protection against opportunism (Gómez-Ibáñez, 2003) but the long-term, complex, and risky nature of PPPs makes it impossible to draft contractual consequences for every possible event in the contract's lifetime. Therefore, they are incomplete.

An approach to deal with the inherent uncertainty in PPP contracts and their incomplete nature is through the distribution of risks. It follows a simple principle that minimizes their economic cost: risks are assigned to the contractual party that is best able to mitigate, bear, or diversify them (Yescombe, 2007). This means that the party to which a risk is allocated will be responsible for the favorable or unfavorable effects that any situation related to the risk may bring, within the normal contract alea. In other words, the party will suffer the downside and enjoy the upside of the risks that it has contractually obliged itself to manage discarding unforeseen, unpredictable, and irresistible conditions. In principle, a well-balanced contract that provides a fair distribution of risks and returns (which will be referred to as the contractual financial equilibrium) will disincentivize opportunistic behavior and prevent renegotiations.

By distributing risks among the parties, the PPP contract seeks to create incentives that promote cost containment and diligence in risk management (Ehlers, 2014). For example, the very nature of PPP arrangements (in what respects to the delivery of a service and not an asset) creates an incentive for expedite execution, as profits will be perceived once the service is being delivered and time delays will be penalized. On the other hand, the allocation of the design, construction, operation, and maintenance risks creates an incentive for the private party to engage the project through a life-cycle perspective: the constructor will optimize its costs in the long-run by investing in designs and materials that provide a better value for money. Such efficiency gains in the cost structure of the project will impact the valuation of the PPP.

It seems that a fair allocation of risks will create the appropriate incentives for the parties to perform diligently and promote project success. Nevertheless, contracts are usually ambiguous and governments share the risks unintentionally as a result of contract renegotiation or as a measure to avoid project distress (Engel, Fischer and Galetovic, 2014).

Force Majeure

French law defines Force Majeure as an event that is unforeseeable, unavoidable and external that makes the normal execution of a contract impossible. The World Bank, in its Public-Private Partnership Legal Resource Center (PPPLRC), defines it as "risks beyond the reasonable control of a party, incurred not as a product or result of the negligence of the afflicted party, which have a materially adverse effect on the ability of such party to perform its obligations". Despite its typification in civil codes, Force Majeure or fortuitous event clauses are commonly included in concession agreements to adjust their scope to the particularities of the project. The objective is to exonerate the concessionaire from its responsibilities due to circumstances beyond its control, that are both irresistible and unpredictable. It works as an insurance in favor of the private party against financial hardship (PPIAF and GIF, 2017).

The details of Force Majeure clauses will be determined by the prevailing legislation and the specifics of the project. However, the intention is to cover events or the consequences of an event that was neither preventable nor foreseeable if and only if the Contractor could not have prevented it by taking steps which it could reasonably be expected to have taken (Dentons, 2013). The type of rare, high-impact events that severely derail demand patterns from their forecasts are usually covered by these clauses, as no due diligence performed by the concessionaire might have avoided or mitigated their effects. As a consequence, it is common that such effects are transferred to the government and compensated with taxpayers' money. As a consequence, the government is absorbing the consequences of materialized risks caused by the planners' incapacity of predicting the future.

4.2.2 Capital Structure

A project's capital structure can be a powerful risk management mechanism over its life-cycle, as it creates incentives for different project participants to pursue a successful outcome. The capital structure of a project clearly defines seniority of claims between different sponsors and the amounts that each one represents. The way in which different sources of financing are tapped determines the way in which they will be paid, a concept usually referred to as the waterfall of cash flows.

In it, it is common to find senior lenders first, with a claim limited to the repayment of principal, interests, and damages (in the case of events of default); followed by junior lenders, whose claim is also limited to loan repayment but subordinated to senior claims; and shareholders, the residual claimant of cash flows. To guarantee debt service and to maintain the operating capability of the infrastructure, it is common that the repayment structure includes a series of accounts and funds. The most common types are the Debt Service Reserve Account (DSRA), which accumulates cash in a reservoir to cover a predetermined number of interest repayments before any other disbursements can be made; a Maintenance Reserve Account (MRA), which sets cash aside for the

prospective payment of major maintenance expenditures; or other types of sinking funds that could be oriented towards subordinate debt or the retirement of bonds. The cash accumulated in these funds will provide comfort to lenders as the effects of temporary shortfalls in project performance will be less severe. However, they are useless when the shortfall is not temporary.

With debt/equity ratios that range between 80/20 to 60/40 (PPPLRC, 2016), lenders bear the majority of the downside risk in an infrastructure project and have the incentive to continuously monitor its performance. Debt is a powerful governance mechanism that acts as an early warning system of financial deterioration and allows for the implementation of corrective measures. On the other hand, equity holders have the residual claim on project cash flows and hence possess the sharpest incentives to lead it to success. As mentioned in Section 2.6.2, equity sponsors are entitled to the project's upside and will rely on their expertise to unlock it.

4.2.2.1 Debt Instruments

There are two main types of debt instruments used in infrastructure procurement: loans and bonds. At the outset, a great majority of projects worldwide is financed by means of loans from financial institutions (Dentons, 2013) due to the possibility of shaping the repayment profile to the particularities of each project (at a variable rate). As the loan is usually provided by a consortium of financial institutions with a clearly defined leader, renegotiations due to covenant breach or events of default are simpler and less costly.

Bonds offer an interesting alternative. The stable, inflation-indexed returns that infrastructure projects can provide are compatible with the requirements of bond markets, specially pension funds. For infrastructure projects, long-term bonds are an attractive fixed-rate source of funds that can be repaid over a longer time frame, with a considerable effect in the project's attractiveness (net present value and internal rate of return).

There are some important obstacles that limit their widespread use. Bondholders are interested in the long-term stable returns of infrastructure assets, not in assuming project specific risks that are particularly concentrated in the construction and ramp-up phases. Furthermore, the diffuse and anonymous nature of bondholders and the lack of a concentrated mandate makes it difficult to achieve consensus that allows a rapid reaction to adverse conditions. Additionally, resources from a bond issuance are commonly delivered in a single disbursement which is not compatible with the execution profile of most infrastructure projects. A strategy to address this issue is depositing the excess of resources in a trust, where they will not depreciate but will not obtain the expected return on investment (phenomenon known as the negative carry effect).

4.2.2.2 Equity

Equity is another important governance mechanism as it creates the incentives for successful project execution. The limited or no recourse characteristic of Project Finance borrowing and the debt-to-equity ratios common to infrastructure deals leads to a very tight structure that provides

lenders with comfort, as was just explained. There are many ways in which equity sponsors can see their dividends locked-up or swept if project performance is not satisfactory. Correspondingly, rates of return for equity contributions will be unequivocally when compared to debt.

Given the intent of achieving project success, occasions might surface when additional equity contributions are required. Such capitalizations can be defined in the contractual documentation and may be triggered by cash deficiencies. Additional contributions might also be voluntary, given a tactical decision made by sponsors. In either case, the approval of senior lenders might be sought.

4.2.3 Contractual Arrangements

Within the SPV, many of the risks that an infrastructure PPP faces can be handled through contracts and agreements with third parties. The following sections present the most relevant ones in terms of performance, cooperation, and financing.

4.2.3.1 Engineering, Procurement, and Construction Contract

The design and construction of the physical infrastructure is contracted by the SPV to a firm with proven experience in similar projects under an Engineering, Procurement, and Construction contract - EPC contract (Ruster, 1999). In it, the contractor accepts full responsibility for delivering a fully operational facility on a date-certain, fixed-price basis - known as lump sum turnkey contract (LSTK).

Once again, the magnitude and complexity of large infrastructure projects creates the possibility of joint ventures and partnerships among smaller construction companies to accredit the necessary experience, expertise, and financial capacity to undertake the LSTK. This implies that the construction company usually does not receive significant retribution during the construction phase, resulting in a requirement of financial muscle to weather cost overruns, contingencies, and financial distress.

As mentioned in numeral 2.4, the fact that PPPs are centered in the provision of a service and not the construction of an asset over a long time horizon creates an incentive for expedite construction where the overall life-cycle costs are considered. As a consequence, engineers will optimize the design so that the Key Performance Indicators (KPIs) specified in the contract are met over its entire duration in the most cost-efficient way. It is common that the firms that make up the Construction Company are also sponsors of the project with equity interests.

The EPC contract allows the SPV to transfer the construction/completion risk to the contractor, that will have to deliver the facilities at the agreed time with strict compliance of technical specifications. If the contractor fails to meet its obligations, it may not only be required to cover the cost overruns out of its own balance sheet (which is why it is probable that the budget contains contingency funds) but also to compensate the SPV in the form of liquidated damages. These

liquidated damages are intended to compensate lenders and equity holders for the interest payments and dividends that are lost due to the delay (Ruster, 1999). It is also common that contractors are required to post performance bonds that guarantee the opportune delivery of the assets and that they are insured with policies such as the Construction All Risk, Advance Loss of Profits, and Miscellaneous coverage insurance policies, among others.

4.2.3.2 Operation and Maintenance Contract

A similar situation is encountered when defining the firm that will operate and maintain the project. Frequently, requests for proposals in a bidding process include a required experience that must be accredited by the operating company which is why consortiums can also be formed. As maintenance may involve important interventions in a project's physical infrastructure, it is common that the Operating Company shares some of the expertise that the Construction Company had. This synergy is facilitated by the life-cycle approach of PPPs and the fact that both construction and operations are bundled together.

In certain infrastructure types, the SPV often enters in offtake agreements with third parties interested in the output of the project. The direct effect of such take-or-pay structures (where the third party is committed to purchasing the product or being penalized) is an effective strategy to hedge demand risk. At the opposite end of the process, it is also possible to hedge the commercial risk associated to fluctuating input prices. In the case of energy generation plants, it is common that bulk supply contracts are signed for fuel and power purchase agreements are set in place for electricity over a given time horizon. The treatment and distribution of potable water may have a similar structure, where the SPV obtains the license to exploit raw water from a reservoir and is committed to supply a predetermined volume to an industry for a set number of years. However, this approach to risk hedging is not applicable to all infrastructure types.

4.2.3.3 Governmental Commitments

Given the magnitude of PPPs both in term of capital required and time frame, it is common that governments agree to maintain relative stability in what concerns the legal and taxation regimes. Additionally, it is common that governments agree to compensate investors in the case of reforms that profoundly affect the project's finances. For example, the concession contract might stipulate that the concessionaire will fully compensated in case of expropriation/nationalization; that all requested permits will be granted to the project given that it fulfills the requirements defined in the applicable legislation; that the government will compensate the effects of any changes in the tax code if it exceeds an agreed upon increase; and that any disputes could be taken to international arbitration if deemed necessary by any party, among others.

These contractual provisions have the effect of reducing the perceived country risk and providing security for investors. As a result, the risk premium requested by bondholders and shareholders should diminish. However, their effect is limited as this type of commitments are not liquid and are contingent to specific events imputable to the public sector.

4.2.3.4 Credit Contract

Given the limited or no recourse condition of project finance borrowing used to fund infrastructure PPPs, much effort and resources are devoted to providing security to lenders. The following sections present some common features of infrastructure credit contracts.

4.2.3.4.1 Project Bank Accounts

It is common that debt (and equity) drawdowns are deposited in an escrow account to maintain a very strict and clear control over the project's finances. This type of structure promotes transparency and efficiency, as the escrow agent can only disburse moneys under very specific conditions and as a result of previously determined events. The main escrow account will usually have a series of sub accounts that offer further detail in the management of project's resources: for example, the resources used in the *Land Acquisition Sub Account* can only be used to pay for land titles once the requirements and conditions defined by the contract have been met. As a result, the possibility of opportunistic behavior by managers to the detriment of lenders can be controlled.

4.2.3.4.2 Cover Ratios

Cover ratios are used extensively in Project Finance borrowing to constantly and consistently assess the financial performance of a project in terms of its capacity to service its debt obligations. Cover ratios serve a similar purpose in Project Finance as financial ratios do in Corporate Finance: analyze the performance and sustainability of the firm over time and in comparison, to others. Additionally, the following are intended to create adequate early warnings of a deteriorating project performance. As a result, intervention by sponsors will be triggered with the purpose of avoiding points of no return. Three main ratios are used in infrastructure Project Finance for different purposes:

- **Debt Service Coverage Ratio (DSCR):** ratio of Cash Flow Available for Debt Service (CFADS) to Debt Service for that period (usually calculated on a six-month basis).
- **Loan Life Coverage Ratio (LLCR):** ratio of total present value of projected CFADS over the full life of the loan to the outstanding debt balance in the period.
- **Project Life Coverage Ratio (PLCR):** ratio of total present value of projected CFADS over the remaining full life of the project to the outstanding debt balance in the period.

The calculation of these ratios is based on a financial model that simulates the performance of the project based on a series of assumptions regarding expenses, revenues, macroeconomic variables, and rates, among others. At the outset, the coverage ratios will be calculated based upon the *base case* scenario developed by the forecasting team or firm. However, it is axiomatic that the assumptions on which a project evaluation rests upon will change over the life time of the project. As a result, several cases and sensitivities will be tested to assess the project's performance under stress. It is common that lenders hire their own forecasting experts to construct their own 'unbiased' forecasts (i.e., free from the optimism and cognitive bias that might affect the sponsors

of the project). Banking cases are usually more conservative than those developed by sponsors, irrespective of their public or private nature (Bodmer, 2015).

LLCR and PLCR are ratios between the net present value of the cash flows that the project is expected to generate and the projected loan values remaining outstanding at the moment in which the calculation is carried out (either the remaining full life of the loan or the entire project). The need for discounting creates the need of establishing a Discount Rate (DR) appropriate for the uncertainty involved. The DR is commonly defined in reference to current interest rates in a similar fashion as the Capital Asset Pricing Model methodology: a risk-free rate plus a risk premium. As the risk profile of an infrastructure project subsides after the completion, the risk premium used to calculate the DR should be lower.

It is common that the cover ratios just described are used to monitor and control project performance. After being analyzed using various scenarios, sensitivities, and stress tests, thresholds are established that trigger specific consequences when violated. A concession agreement might stipulate in its financial annex the target cover ratios that the project should achieve given the assumptions and risks analysis performed, lock-up cover ratios that block any dividend disbursement until the drawback has been overcome, or default cover ratios where the project is in technical default. According to the PPIAF and GIF (2017), the following "credit zones" are common in relation to the credit performance of a project:

- **Strong**: target cover ratios are exceeded or met.
- **Solvent**: target cover ratios are not met but equity distributions are still permitted.
- **Distressed**: lock-up cover ratios are not being met but the SPV is not yet in default. Among possible actions that lenders might take are: block dividend distribution (cash traps), cash sweeps might be activated that affect other project accounts, reserve account money might be applied to service debt, and interest margins could be increased (Yescombe, 2014).
- **Default**: default cover ratios have been breached and the SPV is in technical default. Lenders will be able to accelerate or cancel outstanding loan amounts and exercise step-in rights.

4.2.3.4.3 Covenants and Warranties

Given the limited or no recourse that lenders have beyond the project's assets, it is common that they require a series of warning and control mechanisms to be set in place. Their purpose is to provide lenders with early warnings to detect declining performance (so that the appropriate measures are taken at the opportune moment) and control over the project in the case that it derails. The most common are covenants and warranties that may trigger a technical default.

A covenant is a promise in a contract (Cornell Law School, 2019), that can be positive or negative. Positive covenants can stipulate compliance with contractual obligations, in particular construction and operation in accordance with project documents; compliance with legal obligations, in

particular in relation to the land and taxes; refraining from exercising certain rights and powers, e.g. amend, assign or transfer any project contract; and giving access to the site and records to the lenders' advisers and provide reports and other information; among others (PPPLRC, 2016). Negative covenants can specify that the project will hold no other security and no other debt; that the SPV will conduct no other business, will not be a party to other contracts, nor will it abandon the project.

A warranty guarantees compensation in the case of a covenant breach. For example, a concession contract might provide that the concessionaire will pay a predetermined fine for every day beyond the initially agreed-upon completion date in which the physical infrastructure has not been put in service. On a different case, a clause may specify that a certain level of service in an airport waiting room will be maintained 95% of operating hours and that, in case that the threshold is exceeded, the operator's retribution will be penalized.

As mentioned, the purpose of covenants and warranties is not necessarily to accelerate the enforcement of security over the project's assets but to serve as timely warnings in case of faults and provide control to lenders as needed. The following are examples of mechanisms that might be included in contracts to achieve these goals.

4.2.3.4.4 Cure rights

Cure rights are another feature that warns about possible derailments from contractual obligations. Whenever an obligation subject to cure rights is breached, contractual documents may stipulate a predetermined period of time in which no sanction will be imposed. The purpose of such cure period is to allow the involved parties to take whatever measures are necessary to correct the contractual breach and put the project back on track. A breach that is not corrected during the cure period can result in sanctions, fines, and even technical defaults.

4.2.3.4.5 Step-in rights

In the event of contractual breaches that were not corrected in the cure period (if subject to it), lenders have the right to take control over the project. Step-in rights are defined for specific cases where the incapacity of the SPV to adequately perform its obligations is demonstrated. Despite lenders recourse to the project's assets, a fire sale of the physical infrastructure will unlikely be worth the value of the outstanding debt. As a project's value is directly proportional to its capacity of creating cash, lenders will generally make use of their rights to step in and appoint a substitute entity to take over the project.

4.2.3.4.6 Novation

The substitution of the SPV for a different party that will take on all of the project company's rights and obligations is known as novation. The possibility of novating the project to a third party has to be explicitly described in all the documents of the concession agreement or negotiated with sponsors (and approved by them) to be successful. It is expected that a novation of the concession

contract will be accompanied by a restructuring of contractual obligations related to schedule, budget, and debt service to avoid future events of default.

4.2.3.5 Repayment Structures to Face Cash Flow Uncertainty

Given the vast uncertainties that infrastructure projects face, interesting efforts have been oriented towards the creation of flexible waterfall structures that seek to accommodate the volatility of cash flows. The following exemplify approaches to handle credit risk while reducing costs of renegotiation.

4.2.3.5.1 Deferral of Amortization

Scheduled debt service may be deferred during periods of low cash flow to avoid a default and renegotiations (Fitch Ratings, 2006). Deferred principal, regular and penalty interests (caused by the deferral) must be fully paid before any future equity distribution is allowed. This approach avoids costly renegotiations by acknowledging that cash flow shortfalls are not uncommon but difficult to predict. By introducing the possibility of deferring debt service for a limited time, the project can handle temporary shortfalls without incurring in costly renegotiations.

Deferral conditions must be well established to maintain the project's capacity of servicing future obligations. Managerial action will be essential for the project to adequately react to temporary shortfalls of revenue. If the deferral conditions are exceeded, actual project performance can be used as an input for a renegotiation that adjusts debt service to reality and not the initial expectation. Unfortunately, this structure will not be sufficient to face a future where the system was built for a demand much higher than the real one, as revenue will not be sufficient to generate the expected returns.

4.2.3.5.2 Bullets with Refinancing

A lump sum payment for the entire loan amount paid at maturity with the possibility of being refinanced provides flexibility to deal with short- to medium-term cash flow uncertainty (Fitch Ratings, 2006). By eliminating debt-service obligations, this structure reduces the probability of technical default during the ramp-up phase of the project. However, it is common that it involves a sinking fund that accumulates resources for the bullet repayment or possible renegotiations and that equity distributions are not allowed before either happen.

Once managers possess enough information about how the project operates (in contrast with initial decision making based on expectations), bullets can then be refinanced at terms and rates more consistent with the project's cash flow profile. This structure is an effective way of mitigating the risk of facing financial distress due to revenue shortfalls but does not avoid the possibility of over-building a project due to a wrong forecast. If the financial profile of a project has deviated too far away from the expectation, renegotiating debt service will not be enough to save it.

4.2.3.5.3 Cash Sweeps

In this structure, a predefined percentage of excess cash is used to prepay debt or provide extra security for lenders instead of disbursing dividends to investors. The perceived probability of default for financiers will be lower, as a higher priority is given to debtholders in the pecking order by further subordinating dividends. Nevertheless, a cash sweep will be ineffective if a project is not capable of generating cash to cover debt service due to over-dimensioned or inadequate facilities.

4.3 Planning Phase

This section will focus on how the planning process is shaped or modified when considering the effect of uncertainties. Three different strategies will be analyzed: the approach suggested by the World Bank's PPIAF to manage traffic risk in PPPs through best practices in the development of forecasts; a strategy developed by the Colombian government to phase the development of road projects based on actual traffic; and an approach to adjusting a project's scope based on the its expected revenue-generating capacity.

4.3.1 Improving the Forecasting Exercise

In 2017, the World Bank Group published the report *Toll-Road PPPs: Identifying, Mitigating and Managing Traffic Risk*. This report, supported by the Public-Private Infrastructure Advisory Facility (PPIAF) and the Global Infrastructure Facility (GIF) housed in the Group, seeks to explain how traffic risk can affect the viability of highway PPPs and what actions can be taken to mitigate its effects. The very nature of traffic forecasting creates traffic risk: the exercise of predicting future conditions is prone to errors, uncertainty, and biases. The document claims that these characteristics can be addressed with a resulting reduction in the magnitude of the risk, which can later be efficiently allocated.

Traffic risk, defined as the inaccuracy of traffic forecasts, is identified as one of the most common factors contributing to the failure of some high-profile toll-highway PPPs. When the downside is manifested, it can lead to financially distressed concessionaires, bankruptcies, renegotiations and government bailouts (PPIAF and GIF, 2017). In the opposite case, the perception of corruption, embezzlement, or profiteering by the private sector. Given the difficulty of influencing demand (that is a function of so many different variables both at the macro and micro economic levels), a growing number of financiers have become unwilling to sponsor projects where the government does not absorb the risk or provide guarantees against it.

Given the aforementioned importance of infrastructure, it is in governments' best interest to structure projects around a responsible and reasonable forecasting exercise. To do this, the report states that it is essential to understand the underlying causes of traffic forecasting inaccuracy:

- **Error**: inaccuracies due to involuntary human error that are internal to the forecasting process and occur during the development of the traffic study.
- **Uncertainty:** inaccuracies that are usually out of the control of the forecaster as they represent unexpected changes in the environment in which the project will perform.
- **Bias**: voluntary or involuntary inaccuracies caused by human intention or perception of reality.

The document states that error and uncertainty should (in theory) be evenly distributed (i.e. you are just as likely to over-predict traffic as you are to under-predict it), while bias can contribute to systematic inaccuracies in traffic forecasts (PPIAF and GIF, 2017). In other words, that error and uncertainty should in theory be random and therefore balance out in the forecasting process: an error made in one aspect of the forecast that leads to over-forecasting of traffic, should be counteracted by error and uncertainty somewhere else in the process that reduces the forecast back to its true level. This is why the document focuses on how to address bias in a demand forecasting exercise.

4.3.1.1 Addressing Bias in Demand Forecasting

The World Bank document identifies four important sources of bias and a set of actions that governments can take to reduce them.

1. Delusion (or optimism bias) is described as the optimism and overconfidence intrinsic to human nature that permeates a forecasting exercise. It is therefore involuntary and, in many cases, uncontrollable.
2. Distortion (or strategic misrepresentation) refers to deliberate manipulation of traffic and revenue forecasts to achieve a certain political or organizational goal. The high profile, cost, and impact of infrastructure projects creates incentives for short-termism that may backfire in the future and expose the government to moral hazard.
3. The winner's curse due to unintended overforecasting where information asymmetry leads a bidder to unknowingly over-estimate future traffic activity.
4. The survivor's curse caused by unintended bias where error and uncertainty are positively distributed results in overforecasting.

The authors mention the following measures to reduce bias: a public-sector traffic study conducted by independent advisors, government-side due diligence where the traffic study is compared to similar studies, sharing the base-year travel-demand model with bidders, financier due diligence and financier commitment, penalizing bidders for excessively high forecasts, and ensuring the concession agreement is robust.

4.3.1.2 Discussion

First, the claim that error and uncertainty cancel out will be addressed. After stating that the average of error and uncertainty in a forecasting process should be zero, they recognize that this characteristic might only be true for large sample sizes. The authors mention that the concept may not be true for a single forecasting exercise, as the sources of error and uncertainty can be of such different magnitudes that within a single project a forecasting error might be so great that a compensating forecasting error in the other direction is unlikely. This claim does not acknowledge that engineering systems are non-linear due to economies of scale, discrete capacity choices, and managerial discretion, among others. It also overlooks that the distributions in social systems and small sample sizes are rarely symmetric which is why the average result is not necessarily the most likely. Finally, claiming that results will average out ignores the *Flaw of Averages*. This concept, named by Sam Savage, is based on Jensen's inequality where the average of all the possible outcomes associated with uncertain parameters generally does not equal the value obtained from using the average value of the parameters.

Second, a close study of the proposed measures to reduce bias in traffic forecasting shows that they are based on the notion that a comparative analysis will render a more appropriate result. An adversarial approach to knowledge assessment, that considers the different motivations, incentives, and understanding of reality of the parties involved, is thought to provide better results. However, this is questionable as it implies that one of the studies will be accurate or that a high enough sample size will allow the result to converge to the true value. There is no guarantee that benchmarking bidders' forecasts to the one conducted by the government (or an external advisor thought to be independent) will be effective. Reality is too complex and rife with disruptions to be unequivocally predicted.

4.3.1.3 Least Present Value of Revenue

Despite continuous improvements and developments in forecasting models and techniques, there is a great degree of unpredictability in long-term forecasts (de Neufville and Scholtes, 2006; Cruz and Marques, 2013; Bodmer, 2015). A long temporal horizon implies a significant amount of uncertainties that represent risks for a project: the economic scenario, technological changes, competition with substitutes, cyclicality in market conditions, and black swan events, among others (Geltner and de Neufville, 2018). An important development to deal with demand risk and unpredictable events is the concept of Least Present Value of Revenue (LPVR) developed by Engel, Fischer and Galetovic (2001). In this framework, the duration of the contract is equal to the time required by the private party to obtain the value of revenue included in its proposal, which was selected for being the lowest one. As a result, the contract has the flexibility to absorb discrepancies between the actual and forecasted demand within a preset maximum time frame.

Despite its versatility to deal with uncertainty, LPVR does not fully address the risk of facing financial distress to a revenue profile that is not sufficient to service debt. A project that is on the

verge of defaulting will probably force the government to renegotiate the contract and opening a window for opportunistic modifications.

4.3.2 Successive Scopes

The report *Esquema Metodológico para la Definición de la Gradualidad De Obras En Carreteras* (Methodological Scheme for the Definition of the Graduality of Roadworks) was commissioned in 1999 by the Colombian Government to the consulting firm TTC Engenharia de Trafego e de Transportes. It presents a methodological scheme for the gradual development of roads using the Briceño-Tunja-Sogamoso road (single carriageway) as a case study. The need for expansion is determined through a comparative analysis of demand and existing capacity. The entire analysis is a function of the level of service provided by the road, which is determined by means of two methods: Colombian National Roads Institute (INVIAS) and the Highway Capacity Manual of the Transport Research Board.

The document proposes a series of interventions given the relationship between capacity (service level) and demand as follows:

1. Rehabilitation and improvement of the existing roadway through the extension of the shoulders resurfacing, and improvement of road signage.
2. Construction of a third lane.
3. Construction of a second roadway.
4. Construction of a variant on a single road.
5. Construction of a double carriageway variant.
6. Construction of overpasses.

The capacity of a section under acceptable level of service conditions is calculated through the previously mentioned models. These models define the service level based on the geometric characteristics of the section and the composition of traffic. Among the data used as input to the model are: the length and grade of the ascending slopes, the state of the running surface, the lane and shoulder dimensions, the percentage of heavy vehicles, and the radius of curvature of the critical curve, among others. The document presents ample detail about how to perform these calculations.

The demand is projected through growth rates estimated from factors such as: the region's Gross Domestic Product, the population growth rate, the project's area of influence economic characteristics, the characteristics of the vehicles that will use the road, the region's current motorization rates, and other modes and roads that can capture traffic. Based on this information, the Average Daily Traffic is estimated for automobiles, buses, and trucks at five-year intervals. No detail is given about how the growth percentages were calculated.

A comparative analysis of capacity and demand makes it possible to define a timetable for the execution of interventions in the project term. An iterative multiannual process is carried out in which the adequacy of the level of service provided by the road is verified. In the opposite case, an intervention is scheduled so that the expansion is available in the period in which the violation of the service level is foreseen.

4.3.2.1 Discussion

The document recognizes the advantage of a gradual approach to the construction of infrastructure given the negative externalities that congestion represents for a region's economy. By programming the expansion of capacity following the growth of demand, the relationship between these two variables is optimized in such a way that capital investments are deferred until the time when they will be needed.

However, the document makes no reference to the uncertainty surrounding the forecast. As mentioned, the forecasts are usually 'wrong', and it is possible that the planned interventions are required at different times than scheduled - or simply not required at all.

This can be solved by letting the managers of the Briceño-Tunja-Sogamoso road determine the need and timing of the interventions given an obligation to guarantee an adequate level of service in the corridor. This idea is compatible with the concept of Public Private Partnerships in which the provision of a service is contracted and not the construction of an asset. The concessionaire must guarantee a predetermined level of service associated with a *Key Performance Indicator* to be able to access the entire payment for providing said service.

However, if the execution schedule of the interventions is a contractual obligation, the benefits of postponing some capital investments are maintained, with the aggravating circumstance that they may be unnecessary. In this case, managers lose their ability to react to new traffic conditions and the levels of service provided may be far from optimal.

4.3.3 Scope Ladders

Scope adjustment is part of the normal evolution of infrastructure structuring. Given an expectation of revenue (derived from demand), various features of a project are adjusted to achieve feasibility: characteristics of the built assets, user charges, and contract duration, among others. However, the lack of standardization may lead to corrupt practices intended to favor private interests.

Partnerships Victoria (PV), the PPP program of the Australian State of Victoria, has implemented an approach to evaluating bids when budgets are limited as a *scope ladder*. This tool defines how and in what order of priority certain specifications of a project could be removed or added, in case bids

are over or under an affordability limit set by PV based on the Public Sector Comparator[3] (Victoria State Government, 2016).

In a typical PPP, the scope ladder would not be disclosed to bidders and only used by PV to negotiate scope adjustments if bids are above the PSC. In the case of more complex projects or where the government seeks to maximize the scope, a clearly defined scope ladder would be disclosed to shortlisted bidders alongside the PSC as an affordability benchmark in the Request for Proposals – RFP (Victoria State Government, 2016). The fact that the scope ladder and the PSC are developed simultaneously and included in the RFP promotes efficiency and transparency. By clearly communicating its priorities to potential bidders in the RFP, PV reduces potential conflicts of interest during the comparative analysis between the revenue-generation potential of a project (based on a forecast) and the required investment to achieve it.

4.4 Credit Enhancement

Finally, the mechanisms and strategies to improve the credit profile of a project will be assessed. The purpose is to facilitate a project's bankability, by achieving acceptable returns for the risks involved. Credit enhancement can be used to tap different market segments with different risk appetites. By changing the perceived risk profile of the project, financing possibilities are opened, market failures overcame, and transaction costs reduced (Weber and Alfen, 2016). Unfortunately, excessive credit enhancement numbs incentives as it represents the classic moral hazard problem. Hence, it should be used only to the extent required to access financing.

4.4.1 Government Support

As mentioned in Numeral 2.6.1, public sector involvement is a common characteristic of infrastructure PPPs due to public service nature of the services provided. Government involvement can be passive or active according to the specific conditions and characteristics of each PPP. Active participation is oriented to improve the credit profile of projects and increase their bankability.

The host government can then extend loans, grants, and guarantees to streamline the financing of projects. The social function of government is the main justification for intervening projects with the purpose of levering private participation and finance. Many mechanisms and vehicles exist for this purpose, with their specific characteristics defined by the goals that they seek to advance and the peculiarities of the jurisdiction in which they will be enacted. Among them, it is possible to find minimum revenue guarantees, which cover both debt and equity providers; debt guarantees, covering only lenders and maintaining the incentives for sponsors; and contingent liability funds that can be tapped whenever a risk borne by the public sector is activated.

[3] See Section 2.3

4.4.2 Support by Multilateral and Export Credit Agencies

Guarantees provided by Multilateral Agencies (MA) are intended to facilitate the financing of projects and provide security to investors in risky locations. Their involvement not only has the ultimate effect of reducing the cost of capital, but it also deters unlawful actions by the host government. Given their objective of advancing development, MAs are willing to assume risks that the market cannot bear or which would be prohibitively expensive (Commercial Law and Development Program, 2015).

Export credit agencies (ECAs) have typically been established by governments to assist in the export of goods or services which are sourced from that country (Dentons, 2013). The advantages of ECAs involvement includes:

- Provision of political risk insurance which may not be available from the insurance market, or only available at a cost which makes the project uneconomic.
- Longer repayment periods than those offered by commercial banks, increasing the debt capacity of the project and the return on equity.
- Better risk rating, as a guarantee supported by an ECA can bolster the credit rating and help access lower rates.

4.5 Conclusion

As has been documented, considerable financial efforts are made to address credit risk in Public Private Partnerships and to improve their bankability. Ranging from the structure and details of the agreement, to the planning process, and ongoing operations, a considerable amount of resources are devoted to handling uncertainty. However, while they might provide a sense of security to sponsors, they are lacking when facing uncertainty as they do not address the physical project. Most of the mechanisms described in this chapter are based on a forecast that axiomatically will not materialize as expected. As a result, projects might fail even with the best designed set of risk-hedging mechanisms due to the fact that the future is uncertain. Let us now explore an engineering-based approach to face uncertainty and de-risk projects while complementing traditional mechanisms.

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Chapter 5

THE FLEXIBLE ENGINEERING APPROACH TO MITIGATE CREDIT RISK IN PUBLIC PRIVATE PARTNERSHIPS

5.1 Introduction

Miller and Lessard's (2001) study of 60 large engineering projects ($985 million average cost and 10.7 years average duration) concluded that project success depended largely on the amount of uncertainty in the project and how these uncertainties were managed. Uncertainty management can take many forms, including: avoidance of uncertainty, shifting of impacts to third parties, creating buffers to absorb impacts, or providing flexibility to respond in different ways depending on how uncertainty resolves (Ford, Lander and Voyer, 2002). This chapter introduces the concept of Flexibility in Engineering Design, explains the principles and best practices that can streamline its adoption, demonstrates how it can be applied to infrastructure projects.

5.2 Flexibility in Engineering Systems

The focus on flexibility in engineering represents a paradigm change in traditional engineering design because it presumes that the major requirements of the system are at least partially unknown and indeed unknowable in advance (de Neufville and Scholtes, 2011). It recognizes that risk can manifest in favorable or unfavorable conditions, enables the system to avoid future downside circumstances and take advantage of new upside opportunities. In infrastructure projects, flexible engineering design enables developers to implement economical, staged developments in such a way that the appropriate kind of service is provided when and where it is needed.

Flexible design implies a shift in the managerial approach towards a more proactive one: rather than react passively to what may come, it facilitates effective, timely responses to eventualities (de Neufville and Scholtes, 2011). It thus helps managers to recognize the value of delaying some major decisions and commitments until more information is available. Only time will resolve decisive uncertainties and verify the assumptions about future conditions.

Flexibility can be understood as an insurance policy against the downside of risk as it delays irreversible decisions and investments until there is an explicit need for them. In relation to the upside, it is the investment with the lowest adaptation cost across a range of future conditions. Therefore, flexibility in engineering design should be understood as contingency plans to face uncertainty.

From the engineering perspective, a flexible approach embeds in the initial configuration the capability of developing in distinct ways according to the requirements that appear in the future. As a consequence, capacity increases can be staged, and functional improvements tailored to future needs. By not committing to a definite design for the lifetime of the project, the *option* of following diverse development paths is created. From a financial point of view, this concept is known as 'real options' and is ubiquitous in engineering projects, whether it is valued or not.

5.2.1 Theoretical Foundations

This section discusses the theoretical foundations of real options 'in' projects and flexibility in engineering design. It presents financial options and how they have been adapted to real projects, as well as common valuation models.

5.2.1.1 Financial Options

Derivatives -- futures, forwards, swaps, and options in their plain and exotic forms -- are financial instruments used to manage risk and hedge exposure (Hull, 2012). Of them, options are particularly interesting given their asymmetric nature. A financial option gives its owner the right, but not the obligation, to buy (call) or sell (put) an asset, subject to certain conditions within a specified period of time (Black and Scholes, 1973). As a result, options can limit the exposure to a risk by curtailing the downside while allowing for an unlimited upside.

5.2.1.2 Real Options

Unlike financial options, which deal with financial assets and derivatives, real options regard physical structures or systems (Chambers, 2007). The term real options was coined by Myers in 1977, who argued that the value of a firm includes the real assets in place plus the present value of options to make further investments in the future. The optionality maintains its purpose: it gives its holder the right but not the obligation to delay expensive or irreversible decisions.

Real options differ from financial options in that the underlying assets are real assets that are often not traded and represent, for example, contingent decisions to delay, abandon, expand, contract or switch project components or methods (Garvin and Ford, 2012). Moreover, real option analysis takes the impact of uncertainty on future decisions into account, considering the value of the opportunities that risks create. These decisions require a shift in the managerial mindset so as to recognize the situations in which it is convenient to execute an option, in order to either minimize the damage from or take advantage of an uncertain future. This concept is not new to project

management, as managers recurrently make decisions that shape project outcomes. However, the idea of valuing it is.

5.2.1.2.1 "On" Vs "In"

Real options can be categorized as those that are either "on" or "in" projects. As defined by Wang and de Neufville (2006), real options "on" projects are financial options taken on technical elements, treating technology itself as a 'black box'. On the other hand, real options "in" projects are options created by changing the actual design of the technical system.

Real options "on" projects are mostly concerned with the valuation of investment opportunities throughout the operative phase, do not require knowledge on technological issues, and interdependency/path-dependency is not frequently an issue (Wang and de Neufville, 2006). A close parallel can be drawn in relation to financial options, with some caveats regarding the assumptions that different valuation models make (this issue will be analyzed in more detail in the following section).

Real options "in" projects require a deeper understanding about the way the system operates and its particularities. Said requirement derives from the fact that they result from a conscious decision implemented in the system's design. Nevertheless, such knowledge is not readily available among options analysts, who are generally versed in financial engineering. Consequently, there have so far been a reduced number of analyses of real options "in" projects, despite the important opportunities available in this field (Jimenez Perez, 2014).

A system with the ability to deal with a varied number of uncertain conditions will unmistakably include some features that the contrary will not. Nevertheless, the extra construction cost can be viewed as the premium that will allow for the option to be exercised later. As a consequence, the value of the flexibility embedded in the system or the real option "in" the project will result from the difference between the cost of capital for the execution of the project with and without embedded options.

5.2.1.3 Real Options Valuation Models

Many models have been used to determine the price of real options in real projects. Among them, some practitioners have adapted the Black-Scholes option pricing model is the most well-known solution to the option pricing problem as it applies to those European call and put options that do not pay dividends (Ishii, 2007). However, this relatively simple method is not applicable to real projects as the underlying assumptions – related to volatility, price, duration, risk-neutrality, well-behaved future asset values, complete markets for assets, the independence of option holders from the future performance of the underlying asset, and no arbitrage conditions – limit the use of the approach (Garvin and Ford, 2012). Thus, it is very difficult to apply it to large-scale complex engineering projects targeted in this thesis.

Given that traditional methods for analyzing optionality are not applicable to real projects, the most appropriate alternative consists on studying the expected performance of the project under various future scenarios. A widely used method for pricing options is the Binomial Lattice Model developed by Cox, Ross and Rubinstein in 1979, a more simplified discrete-time approach to valuation of options compared to the Black-Scholes option pricing model (Trigeorgis, 1996). It is referred to as a binomial model because it assumes that, during the next time period, the price of the underlying asset will evolve to one of only two possible values. The recombinant characteristic of the binomial lattice tree reduces the possible outcomes for N periods to expiration date from 2^N to $N+1$. This approach can illustrate the intermediate decision-making processes between $t=0$ and the exercise of the option (early exercise of an American option). Furthermore, this method is very effective if only one uncertainty is being modeled, but difficult to adapt to several simultaneous uncertainties.

Monte-Carlo Simulations are an analytical method that generates the statistical distribution of possible outcomes corresponding to probability-distributed sampled inputs (Ohama, 2008). They are a powerful tool to efficiently evaluate various uncertainties simultaneously through a model of system performance and summarize the distribution of possible performance consequences graphically (de Neufville and Scholtes, 2011). The computational capacity of current computers makes the implementation of Monte Carlo simple.

5.2.2 Valuation Metrics

As has been explained, the analysis required for Project Finance borrowing is based on the expectation of cash flows the project will generate. The Discounted Cash Flow (DCF) analysis is the generally preferred method for establishing the value of an asset not set in an active market (Brealy, Myers and Allen, 2014). It is a fundamental valuation methodology broadly used by finance professionals and is premised on the principle that the value of a company, business, or asset can be derived from the present value of its projected free cash flow (Asquith and Weiss, 2016). Unfortunately, it has significant limitations in dealing with uncertainty and flexibility as the risk of subsequent cash flows can change as development proceeds or new information is received (Trigeorgis, 1996).

The extrapolated cash flow rests on a pro-forma financial statement modeling exercise based on a series of assumptions that define the periodic variation of assets, liabilities, and equity. These premises are a simplification of reality and the value of the cash flows will be sensitive to small changes in some input values (e.g., interest rates, exchange rates, economic growth, etc.). Therefore, it must be recognized that, by construction, DCF valuation estimates will be imprecise as the underlying fundamentals of the project will undeniably change over the life time of a project (Bodmer, 2015).

5.2.2.1 Traditional Approach

The traditional approach to project valuation rests upon metrics that provide simple decision rules regarding capital investments. However, a single number does not completely cover the complexity of the risk exposure of long-term infrastructure projects. This section presents the main metrics currently used.

5.2.2.1.1 Net Present Value

The net present value (NPV) of a string of cash flows is an indicator of value that can be calculated as the difference between the revenues and expenses that a project generates in present terms, discounted by means of a discount rate. The following expression defines the net present value of a series of cash flows:

$$NPV = \sum_{t=0}^{T} \frac{C_t}{1 + r^t}$$

Where:

C_t: the cash flow at time period t

r: the periodic discount rate

T: total analysis time frame

t: time period under study

As a general rule, a project with a positive NPV is desirable as it creates value while one with a negative NPV destroys it. If an NPV is equal to zero, the project only produces the opportunity cost of capital which is why an investor would be indifferent to it.

5.2.2.1.2 Discount Rate

The NPV's calculation is based on the concept of the Time Value of Money (where money in the present is worth more than money in the future due to its potential earning capacity and lower uncertainty) which is why the choice of discount rate is critical for the results of a DCF analysis. The discount rate seeks to embody the marginal cost of opportunity of the capital that is being invested. Various methodologies can be used to calculate it contingent upon what type of analysis is being performed (i.e. the Weighted Average Cost of Capital might be used to analyze the value of the project given a capital structure while the Capital Asset Pricing Model might be used to determine the cost of equity or the cost of debt).

Given the compounding nature of the DCF analysis, the NPV is highly sensitive to variations in the discount rate being used. When considering the intrinsic difficulty of precisely calculating it and that changes in discount rates are easy to justify, it can be understood why the incentives to manipulate it are powerful: slight changes in its value can bring investment-grade to a project.

It is common that practitioners add risk premiums to risk-free discount rates to account for risk. When modifying the discount rate to account for risk, the effect of uncertainty is less explicit and transparent. A good example is the country risk premium, which seeks to represent the additional return that investors will demand when investing in a country with a latent political risk. However, there is no theoretical justification for its use (Sabal, 2004) and might mislead potential investors.

5.2.2.1.3 Internal Rate of Return

The internal rate of return (IRR) is a financial metric very similar to the NPV that acts as an indicator of profitability rather than value. Unlike the NPV, the calculation of the IRR does not require an estimation of a discount rate for the project. When trying to define the effective, periodic profitability of an investment, the IRR established the profitability obtained by the resources that stay invested during the execution of the project. As a general rule, IRRs that are higher than a given opportunity cost are sign of profitability. The following equation is used to calculate the IRR, and usually involves a polynomial equation which cannot be solved analytically:

$$0 = \sum_{t=0}^{T} \frac{C_t}{1 + IRR^t}$$

Where:

C_t: the cash flow at time period t

T: total analysis time frame

t: time period under study

The main drawback of the IRR valuation method is that it considers that the cash flows are reinvested at a rate equivalent to the IRR itself. Additionally, in projects in which there are negative cash flows in the operation phase, the calculation of the IRR may be wrong due to the existence of more than one root that satisfies the polynomial equation. Given its complexity, McKinsey & Company (2004) suggests that "most straightforward way to avoid problems with IRR is to avoid it altogether."

There is an alternative: the Modified Internal Rate of Return (MIRR) defines investment projects with two unique cash flows: expenses in the initial period and revenues in the final one. The cost of capital and the interest rate are used to consider the time value of money in this calculation.

5.2.2.2 Stochastic Approach

The identification of the best opportunities for flexibility requires the implementation of different measures of value. Just as real options are situated between standard engineering practice and finance, so must the metrics be. Analyses performed over distributions of results provide much more information than point values. The following figure shows the typical results that a Monte

Carlo Simulation would produce (See Figure 8). A probability distribution function of net present values conveys much more information than just the expectation or average result.

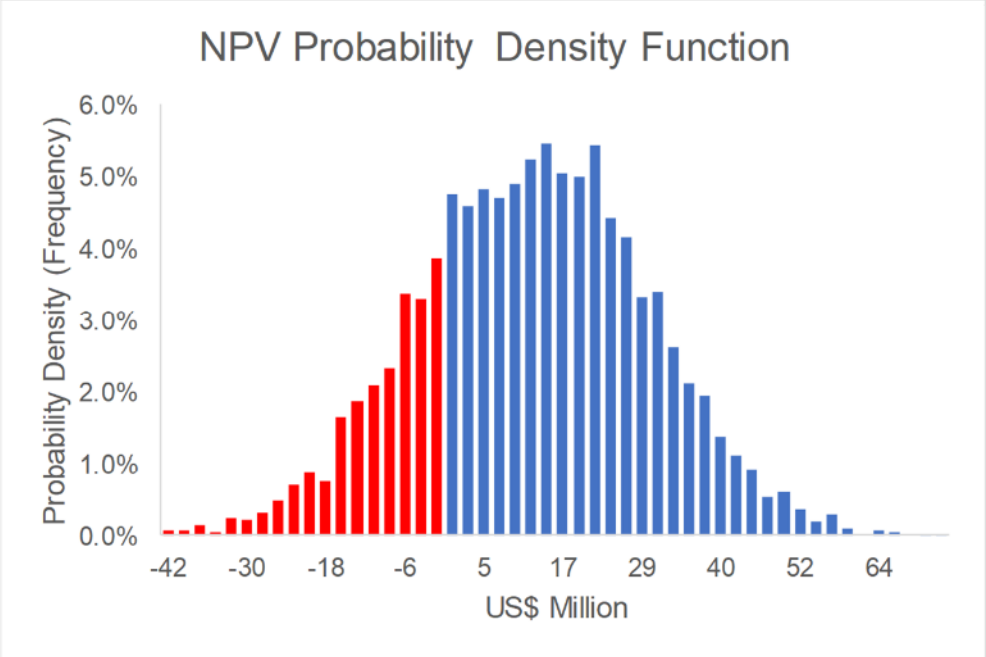

Figure 8 Probability Distribution Function of Net Present Value

Another useful instrument derived from financial engineering is the cumulative distribution function or value at risk and gain diagram (VaRG), a convenient way to display the distribution of possible results (de Neufville *et al.*, 2010). It builds upon the value-at-risk (VaR) concept used by bankers to identify the risk of the expected in a given time horizon and with a defined occurrence probability (Hull, 2012). Many metrics can be read from a VaRG curve (See Figure 9), including:

- The expected net present value (ENPV), which is the abscissa for which the 50% ordinate crosses the distribution function.
- The maximum and minimum values
- The probability associated to negative NPVs, which is the ordinate at which the distribution function crosses the 0 abscissa.
- The volatility of the return, which is defined by the range of the distribution.

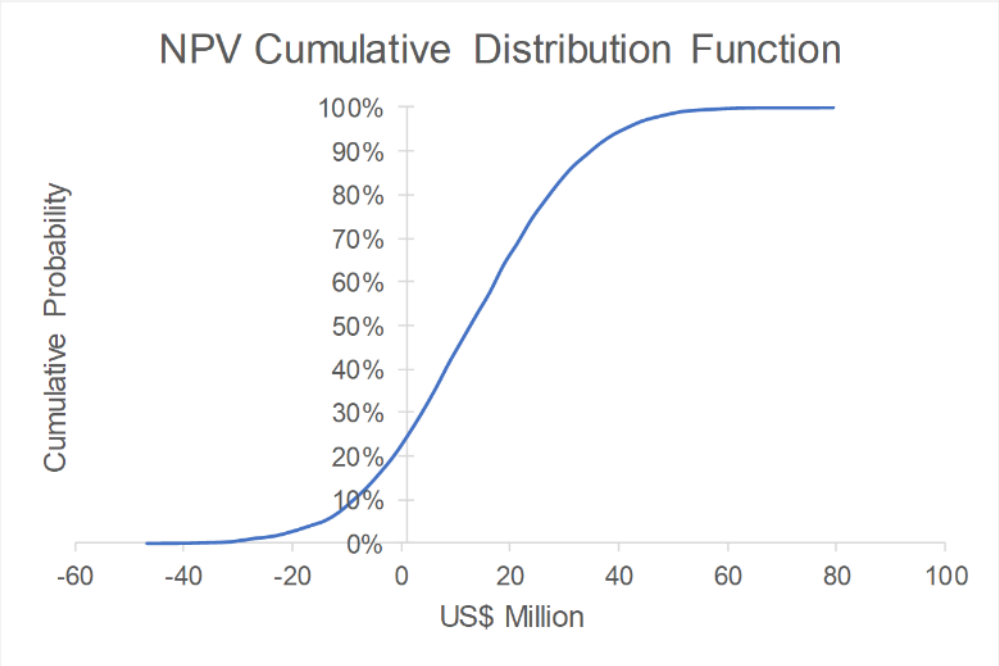

Figure 9 Cumulative distribution function for the project NPV

A project´s risk exposure can be hedged at the design phase by shifting the VaRG curves to the right as much as possible, resulting in a higher ENPV. It is also convenient to reduce the down side tail (in the form of put options) and increasing the upside tail (as call options).

5.3 Flexible Engineering in Infrastructure PPPs

This section provides the principles and best practices that can facilitate and streamline the implementation of flexible engineering design in infrastructure PPPs. The formulation and implementation of Strategic Plan has the potential of increasing the attractiveness of financing thanks to the reduction of the risk exposure.

5.3.1 Principles

The flexibility to postpone irreversible investments while maintaining implementation capacity can improve the long-term economic performance of infrastructure projects and, in consequence, their bankability. The mechanics are simple: when the exposure to the downside of risk is diminished and the project is designed to more easily take advantage of the upside, the overall expected (average) value of the project increases.

As defined by de Neufville (2015), the improvement of the expected economic performance of infrastructure projects builds upon three principles:

1. Recognizing that forecasts are 'always' wrong.
2. Planning strategically for a range of possible future needs.
3. Implementing a Strategic Plan that reduces implementation costs across different futures.

First, by recognizing that forecasts are 'always' wrong, in that future conditions will most certainly diverge from expectations, planners can shape the design process differently. As was presented in Numeral 3.3, forecasts are axiomatically wrong. Markets, demographics, technological development, and politics are very dynamic and not constant over time. Widely sought disruptive innovation will break trend projections and lead to unexpected results.

Second, a Strategic Plan that considers a range of future possible needs and outcomes but defers irreversible investments reduces the downside exposure to risk. Postponing investment decisions until actual conditions validate them is financially efficient, especially when future conditions are uncertain and the future might not unveil as expected. This planning process will initially require more resources than the traditional one, as it has to consider many more 'futures' and embed in the design the capability to accommodate their requirements. Additional efforts will endow flexibility to the system and allow managers to more efficiently shape the outcomes of the project.

Finally, a flexible and staged design that considers more than just the most-likely scenarios, but trend breakers and disruptive innovation, will allow for a more efficient response to new information. Economies of scale might be sacrificed while following this approach, but the arguments in their favor are not decisive in the light of massive uncertainties. Disruptive innovation might change the way in which people transport themselves, communicate with each other, and obtain water and electricity in ways that we cannot fully anticipate or comprehend yet.

A phased development is an effective strategy to deal with the uncertainty of the project, and its impact on investors. It reduces the cash flows with higher impact on the NPV (high initial capital outflows) and may defer or avoid future expenses. A staged development implies a series of real options on the project: investing a portion of the capital at the initial stage of the project, or the option to defer, allows the project managers to acquire more information before taking a decision regarding future phases. Therefore, management can take advantage of positive future conditions (growth option) and reduce its losses in negative ones by deferring the investment or abandoning the project. The option to abandon represents the management's ability to withdraw from a project permanently or temporarily, with the intention of reducing future losses.

Phases in a staged infrastructure development can be deployed by considering three different variables, all as a function of time. Once the designers have embedded real options in the initial

design, project managers can shape future expansion by adjusting the size, location, and function of modules:

5.3.1.1 Size

The choice of capacity is an essential element of the flexible engineering design approach as it seeks to tailor the supply to the demand. It is the main adjustment mechanism of a modular, staged development and provides the tactical means to face risk. A manager's capability of influencing the size of subsequent phases is constrained by the characteristics of different infrastructure types and its costs. Discrete capacity increments are common in high-voltage transmission lines or rail tracks (there is no such thing as half a rail track), while schools or prisons may be expanded to particular requests (a school can have 20, 30, or 40 classrooms and a prison might be able to accommodate 300, 600, or 900 inmates).

5.3.1.2 Location

The capability of managers to influence the location of future developments is defined by scope of the concession deal. This scope can be thoroughly specified, pertaining a predetermined site (e.g. construction of a health care facility in a given location) or not specific: e.g. the provision of health care services in the state of Massachusetts. Managers will have more options to tailor the provision of the service through the engineering design in terms of location of subsequent phases in the latter than in the former.

5.3.1.3 Function

The function of future phases can be designed to cater to different needs. As more information is gathered, the design of the initial phase might not be the most efficient way of providing specific services. For example, when planning for the expansion of a Combined Cycle Gas Turbine generating plant the design may consider that more efficient systems might be available in the future and not lock in the design to the specifications of current technologies.. As a result, the initial design would try to reduce possible constraints as much possible.

5.3.2 Best Practices

The best practices for improving the expected economic performance of infrastructure investments are (de Neufville, 2015):

1. Recognition and description of the relevant uncertainties.
2. Calculation of the range of possible impacts of these uncertainties on the project.
3. Identification of the design features that improve the expected economic performance of the project.
4. Definition of a Strategic Plan for the potential implementation of phases.

5. Justification of the strategy to key stakeholders and sponsors in terms that are intuitively understandable.

The following sections describe in detail the best practices just enunciated.

5.3.2.1 Recognition and Description of the Relevant Uncertainties

The first step to formulate a strategic plan that de-risks infrastructure investments is based on the concept that forecasts are 'always' wrong (which has been extensively addressed in this document - see Numeral 3.3). By recognizing that the future is uncertain and that forecasts of future conditions and activity are unlikely to be accurate, an exercise of exploring alternative scenarios can begin.

Changes in markets, technology, demographics and political conditions should be considered even if they seem unlikely at the moment. As the options embedded in the project will be shaped after the uncertainties that are considered during the design process, it is crucial to move beyond most likely scenarios and evaluate extraordinary events.

Determining the distribution of the risks faced by the project is an important exercise and will be an input for the risk analysis simulations. Historical information is relevant, but it is essential to consider situations out of the ordinary. This approach implies a change from designing for the average of conditions (whether expected or historical) to designing an initial stage (or starter) that will easily adapt to a range of future conditions. As a result, the negative effects of the flaw of averages (as described in Numeral 4.3.1) are mitigated.

5.3.2.2 Calculation of the Range of Possible Impacts

Subjecting a traditional project finance model to thousands of iterations under random selections of probabilistic inputs produces distributions of stochastic results and a more realistic image of the project's performance. Managers can then perform sensitivity analyses to determine the main variables and conditions that should be addressed.

Integration between technical and financial models is essential to achieve a better understanding of the possible future scenarios. As static inputs in the technical model are replaced by distributions (to reflect the uncertainty of assumptions), an integrated model that can accurately represent the financial consequences of uncertainty is central to the analysis. To achieve this, collaboration between technical and financial advisers will help to reduce the complexity of the integrated model.

5.3.2.3 Identification of Design Features to Address Risk and Uncertainty

After modeling the project's performance in thousands of scenarios, it is possible to identify the elements of the engineering design that exacerbate the project's exposure and could be strategically modified to mitigate it. This requires a collaborative effort where engineers, managers, and lenders

determine how the project will be deployed in terms of size/capacity, location, and function. An initial phase (starter) would be designed in such a way that it minimizes the cost of implementing alternative future phases across a range of different scenarios. This approach sacrifices economies of scale but defers irreversible investments, avoids inappropriate or unnecessary facilities caused by changing conditions, and reduces the risk of loss. Once the market conditions signal the need for an adjustment in the project's size/capacity, location, and/or function, managers will be able to implement new phases at a lower cost.

5.3.2.4 Definition of the Strategic Plan

The previous analyses must be condensed in a Strategic Plan that defines the potential phased development of the project. In it, the real options that have been embedded in the design are clearly described (with their potential use) as well as the triggers that should be considered before expanding. As has been mentioned, the initial phase of the project is the key to unlocking the full potential of PPPs. This starter features the lowest cost of implementation for the range of future conditions previously identified.

Posterior phases are implemented when the conditions are favorable and signal the need for additional capacity. A very important set of inputs to effectively determine the trigger for intervention are the Key Performance Indicators (KPIs) defined in the concession contract. As failing to comply with KPIs may result in revenue deductions, it is in the managers best interest to maintain the operating conditions in them defined.

In the process of hedging a project's exposure to multiple risks, it is likely that designers include flexibilities that are mutually exclusive. Therefore, an ex-post analysis would probably reveal that not all of the real options were exercised. This does not necessarily imply that the resources were spent wastefully: one does not see fire insurance as a waste of money when assets do not catch fire. Not needing it does not mean that it did not hedge an exposure to risk.

5.3.2.5 Winning the Support of Key Stakeholders

The widespread implementation of flexible engineering designs in infrastructure development requires a shift away from the traditional approach that must be adequately transmitted to key stakeholders. The main argument against the implementation of a strategic plan is that the initial phase (or starter) is a more expensive version of a similar asset – due to all the flexibilities embedded in the design – that may never be used. It is therefore essential for advocates of flexible designs to communicate the importance of considering the entire life-cycle of the project (which is one of the main characteristics of PPPs -- see Numeral 2.4) and how this approach provides better expected performance at lower costs in present values. Without a thorough justification of the investments in flexible features and why it is desirable, project developers may face substantial opposition as flexibility might sometimes come at a cost.

The implementation of a strategic plan can *de-risk* an investment in infrastructure as it reduces the initial capital expenditures which implies that there is less to lose. By avoiding unproductive investments under the same range of risks and uncertainties, the financial outlook of a project is improved. On the other hand, the project is *future proofed* by the deferral of investments until the conditions justify future phases. As investments are postponed (or eliminated altogether), the present value of cash outflows is reduced with a positive effect on the project's NPV and IRR. When investments are triggered, the information available that was only revealed by the passage of time can be used to implement the appropriate designs for the new conditions. As a result, future phases will increase the profitability of the project by tailoring the system to actual needs.

The approach that developers should employ when addressing key stakeholders should depend on the objectives that they are trying to advance by being involved in the project. When targeting debt providers which provide most of the capital and have the highest value at risk (see Numerals 2.6.2 and 4.2.3.4), the risk mitigation features of a flexible approach to infrastructure development must be stressed. Equity providers, who are last in the pecking order and are entitled to the project's revenue after debt has been serviced, would be in favor of a flexible after understanding that the project's ENPV increases and the possibility of exploiting a project's upside potential is levered. In the case of the government, developers must show that the social and economic externalities of the project will not be affected by the flexible development of the assets. As the Strategic Plan has been laid out to guarantee the compliance with KPIs, sponsors have the incentive to provide the right infrastructure to avoid revenue discounts.

5.3.3 Case Study: LNG Plant

The following sections will analyze in detail the previous items as they apply to a fictional development of an on-shore liquefied natural gas (LNG) plant under uncertainty. In it, Cardin *et al.* (2013) investigate the effects of uncertainty on key strategic factors affecting the design and development of the LNG production system to provide fuel for vehicular use in southeast Australia. The study's objective is to identify designs that provide better expected economic value over the entire lifetime of a project, in comparison to the typical outputs from standard design and project evaluation. The benefits of providing managers with the ability of shaping future phases in terms of size, location, and function are explored.

5.3.3.1 Recognition and Description of the Relevant Uncertainties

The successful development of downstream LNG facilities is influenced by a wide range of socio-technical factors (see Figure 10). Included are investment uncertainties for vehicle and LNG suppliers, consumer uncertainty regarding realization of benefits derived from the technology, and policy uncertainty for government. Specifically, uncertainty surrounding future diesel prices and how it affects the adoption of LNG technology in vehicles; the global price parity for natural gas; the timing of vehicle technology improvements, specifically in what concerns conversion to LNG; the long-term industry cost of capital; the governmental approach to carbon trading, carbon

taxation, and energy policy; and future legislation regarding vehicle emissions were identified. All these factors result in important market demand uncertainty that must be considered to achieve a realistic valuation of the project.

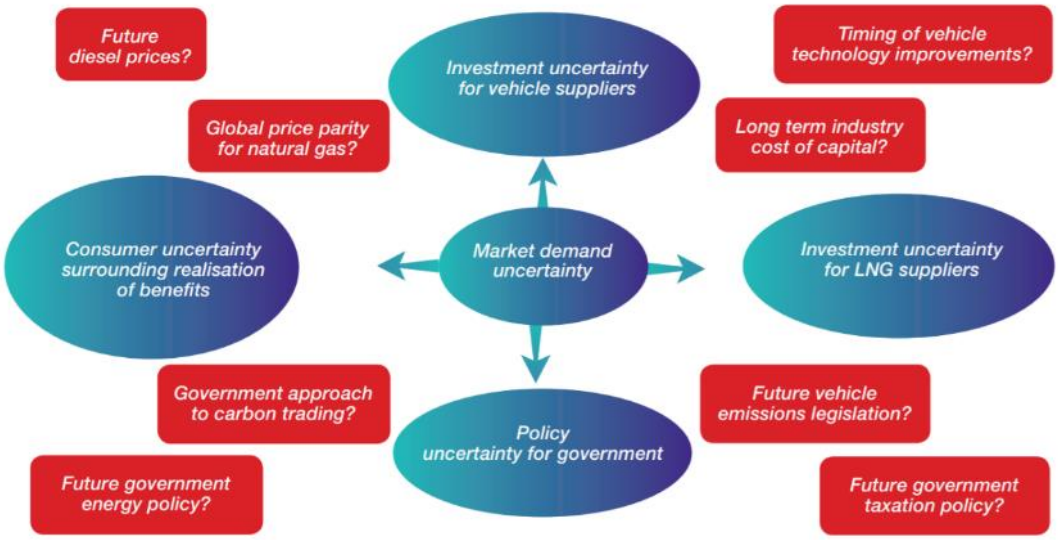

Figure 10 LNG demand as the key source of uncertainty in the heavy transport sector (Cardin et al., 2013)

5.3.3.2 Calculation of the Range of Possible Impacts

The effects of the most important uncertainty parameters on LNG demand are modeled based on an S-curve over the period of study. The rationale behind the selection of the S-curve model is that demand for LNG initially grows slowly for some time, because the market and LNG infrastructures are evolving. Then over time demand increases exponentially, and finally growth tapers off as demand approaches a saturation limit *(Cardin* et al.*, 2013)*. A random parameter is introduced in the equation describing the S-curve as a way of simulating uncertainty. Figure 11 exhibits twenty iterations of the S-curve model of demand for LNG.

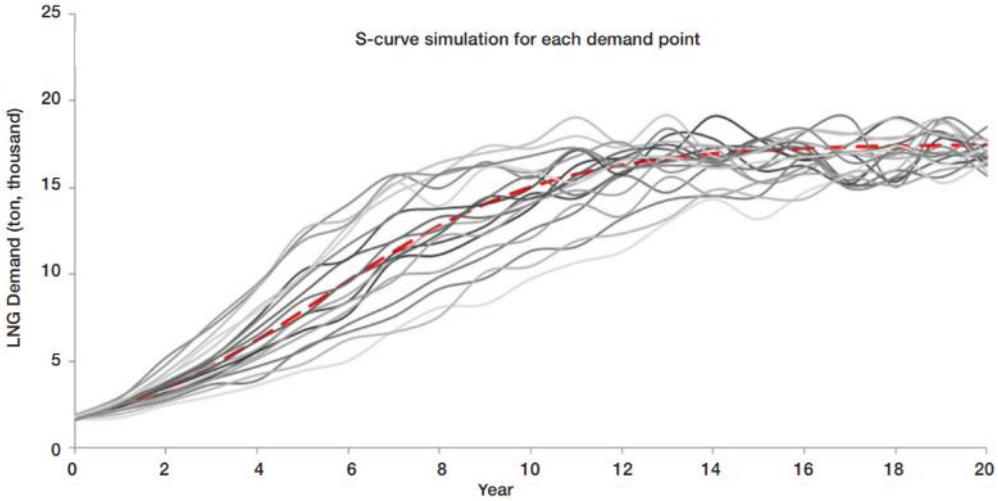

Figure 11 Simulation of LNG demand during the life-cycle of the project for one demand point (Cardin et al., 2013)

5.3.3.3 Identification of Design Features to Address Risk and Uncertainty

In the study, the flexibility analysis is centered on the size/capacity dimension as it is simpler to model and quantify in a general context. Adjusting location and function of subsequent phases is a function of very specific future conditions and characteristics. Despite not being valued, the capacity of adjusting them only improves the financial performance of the project. Two alternative designs for development of the LNG facilities are studied. A main production site dedicated to a centralized LNG plant will be compared to five decentralized demand points equipped with filling station facilities. All sites have access to the on-shore pipeline distributing the natural gas. In the main production site.

First, one centralized design following the traditional approach is proposed with a capacity of 250 tons per day (tpd) of LNG. In it, economies of scale determine the optimal capacity in a main production site located close to the center of the influence area. LNG is produced in the central plant and transported to market sites using fuel trucks. Figure 12 presents the proposed centralized development.

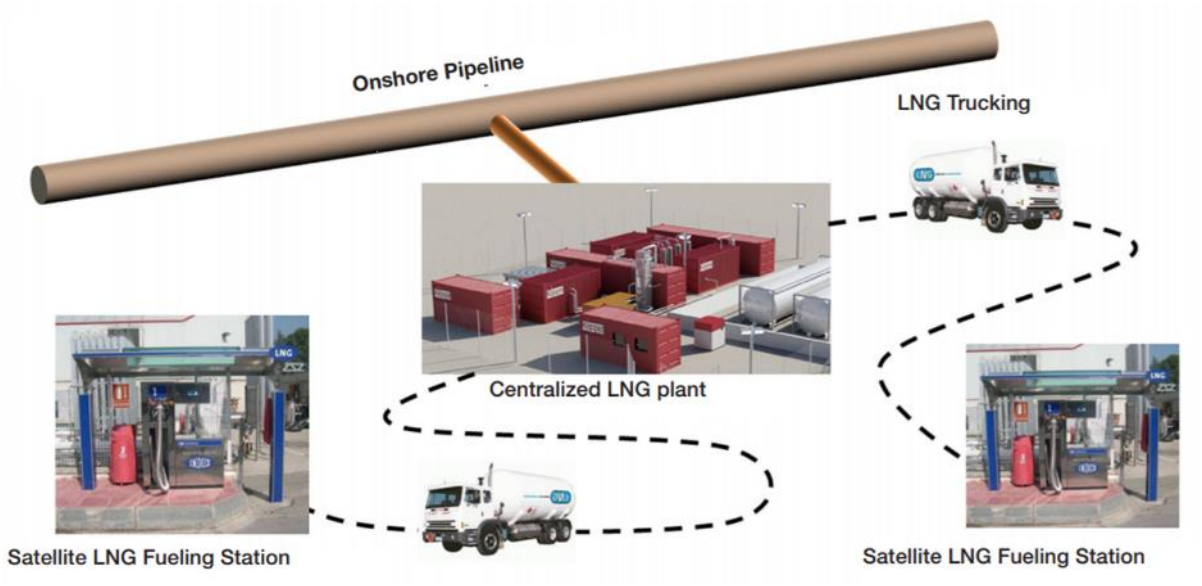

Figure 12 Centralized design alternative (Cardin et al., 2013)

On the other hand, a decentralized design consisting on a phased development of 5 different sites is studied with the purpose of showing the benefits of altering the location dimension of a project. Each one of these sites features a smaller, modular LNG plants (initial capacity equal to 50 tpd of LNG) with the embedded flexibility to expand capacity as deemed fit. Figure 13 presents the proposed decentralized development.

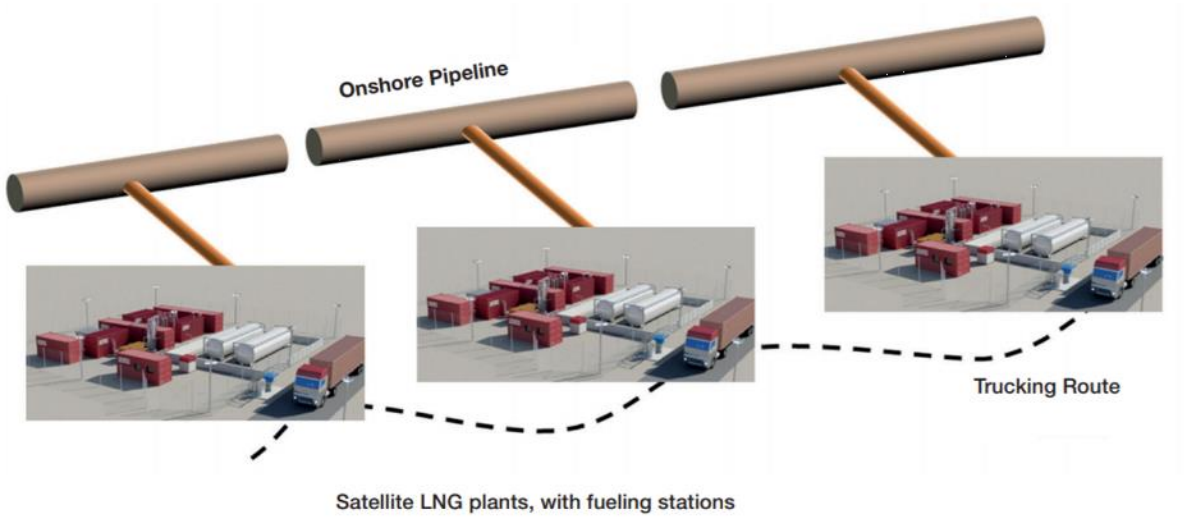

Figure 13 Decentralized design alternative (Cardin et al., 2013)

The performance of both alternatives under uncertainty is assessed through simulations of random demand paths over the project's life-cycle. Managerial discretion is modeled by introducing

conditional statements in the financial model that trigger capital investments in size/capacity expansion. When demand reaches an 85% of installed capacity (50 tpd), investments in additional 25 tpd are executed.

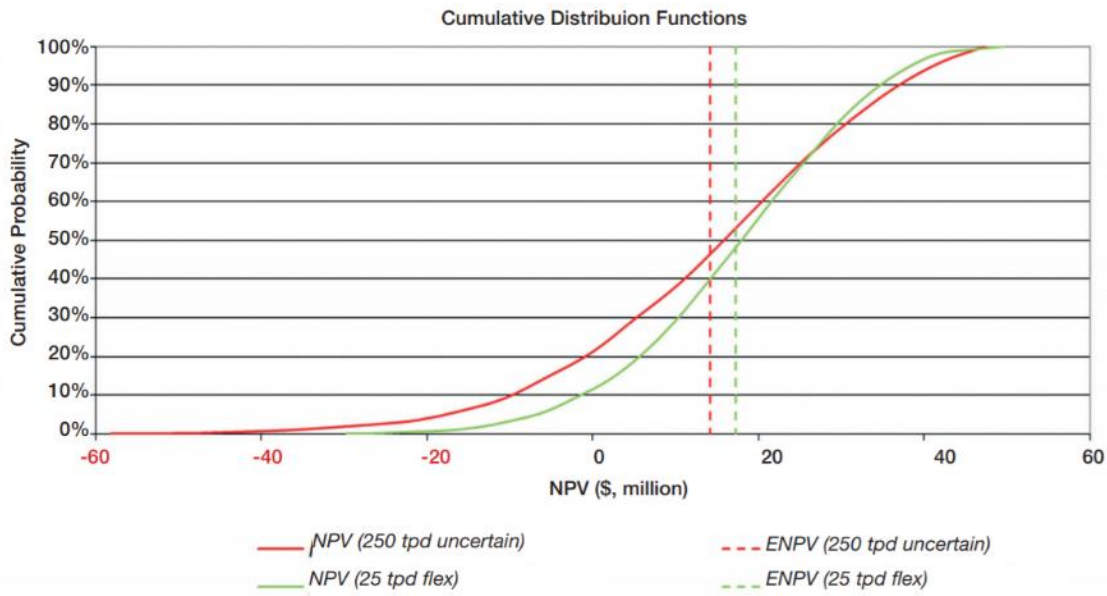

Figure 14 Cumulative distribution of NPV based on 2,000 LNG demand scenarios (Cardin et al., 2013)

Two thousand different demand scenarios are evaluated, and cumulative distribution functions built based on the results (see Figure 14). The flexible approach significantly reduces the downside exposure, which is shown in the retraction of the left tail of the green distribution in comparison to the red one and the P5 values showed in Table 3 (-$5.81 vs -$20 million). The P95 for both developments is practically identical ($40.73 vs $41 million) which reveals that value is not lost as a result of implementing a decentralized strategy. The ENPV of the decentralized design (green dashed line) is $18.45 million, as compared to the ENPV of the centralized system equal to $13.60 million.

Table 3 Summary table for centralized and decentralized alternatives (Cardin et al., 2013)

Metric	Centralized Design (Inflexible)	Decentralized Design (Flexible)
Initial capacity (tpd)	250	125
Mean NPV*	13.60	18.45
P5*	-20.00	-5.81
P95*	41.00	40.73
Standard Deviation*	18.56	14.29
Initial CAPEX*	154.36	125.00

*Values in Million $

5.3.3.4 Definition of the Strategic Plan

The Strategic Plan, after deploying the modular capacity in five different locations, is to constantly inspect the market to determine the moment when the capacity of each location should be updated. In this case, arrangements for expansion must be enacted when demand reaches 85% of the installed capacity.

It is important to mention that the Strategic Plan can be updated during the operating phase as more information is recollected. If the growth in demand is strong or the government rolls out incentive packages for the shift towards technologies the pollute less, managers might decide to increase the scale of subsequent phases to take advantage of favorable conditions. In the opposite case, where the market signals are negative, managers could decide to refrain from expanding the infrastructure.

5.3.3.5 Winning the Support of Key Stakeholders

When approaching the key stakeholders of the LNG plant, the developers must stress how the proposed approach reduces the exposure to losses and increases the expected return while maintaining the upside potential. In other words, the project is de-risked or insured against unfavorable conditions and future-proofed as it can exploit favorable ones.

5.4 Options by Infrastructure Type

This section presents alternatives for flexible developments in selected infrastructure types. It is based on the dimensions of flexibility defined in numeral 5.3.1 and considers a PPP contract or Project Finance deal as its functional unit. The strategies or mechanisms here presented involve physical modifications of the systems (CAPEX) in an ascending order, ignoring operational improvements or modifications.

5.4.1 Roads

5.4.1.1 Capacity

The throughput of a road can be increased by distinct strategies. The construction of additional lanes seems to be the most obvious strategy to increase capacity, by initially addressing critical segments as needed before considering an overall expansion. The logic is that a wider cross section will allow a higher flow of vehicles, given that all other conditions remaining the same. However, other strategies should be considered before investing in additional lanes. The objective of these strategies is to reduce the disturbance of the free flow of vehicles. Overpasses are an initial measure to eliminate the disruption that at-grade or lighted intersections might provide. Whenever a road crosses an urban center whose activity is starting to interfere with the free flow of traffic, a bypass can be built to reduce congestion in the urban area and improve road safety. Another measure that can be used to increase the capacity of a road is the modification of the radii of curvature (and

cambers) to allow higher speeds. This strategy may involve higher capital costs but may bring significant benefits to the throughput.

5.4.1.2 Location

Modifying the layout of an existing road is limited by the origin-destination requirements defined in the concession contract. It is common for road infrastructure contracts to define the points that the road must connect following certain design parameters (related to maximum speeds, slopes, and safety conditions, among others), but not an exact path that the road must follow. Thus, the concessionaire must define the techniques and technologies that will be used to connect the origins/destinations. For this reason, the services provided by a road are defined by the points it connects -- i.e. the road between A and B offers a connection between A and B. This means that the modification of the location of road will not necessarily improve the provision of the service but may result in significant expenses.

Given the magnitude of the investments associated with the preparation of the land, leveling of the subgrade, removal of obstacles, and cuts and fillings of material, the Strategic Planning process will contemplate an initial layout that allows future expansions in the most efficient way possible. This can be achieved through a design that foresees possible expansions but does not commit to these until the traffic and market conditions make it necessary. To maintain the flexibility of the system and keep the options alive, it is necessary to define a right of way greater than that initially required (a technique known as land banking).

5.4.1.3 Function

The nature of the services offered by a road infrastructure project implies that any vehicle that can be contained in the dimensions of the road can be served. This means that the emergence of autonomous, electric, or personal transport vehicles will not necessarily require structural interventions in the existing infrastructure. However, structural reinforcements may be necessary in the case of mass transport systems to ensure the adequacy of the pavement's bearing capacity.

5.4.2 Airport Airside

The airport's airside refers to the infrastructure dedicated and required to the safe operation of aircraft. It usually encompasses runways, taxiways, platforms, and similar structures that support the air service.

5.4.2.1 Capacity

The critical element of the airside of an airfield is the runway, as it is the element where aircraft perform the transition between the ground and the air. As a result, the throughput of a runway system can be increased by reducing the utilization time of each aircraft. This can be achieved by strategically placing high-speed exits that facilitate vacating the runway without deaccelerating to taxi speeds within the runway. An efficient surface movement from/towards the runways can also

be enabled by the construction of additional taxiways. It is common that major international airports have a network of taxiways that allow for the movement of aircraft within the airfield without disrupting runway operations.

The ultimate increase in airside capacity is the construction of a new runway. It is clear that the construction of new runways is the most difficult option in the absence of a long-term planning process, given the magnitude of the land required to do so. If investments in additional runways were not considered at the outset, the costs of resettling real estate developments incompatible with aeronautical activity can be prohibitive and, in many cases, prevent the growth of airports.

An interesting distinction can be made here between parallel and intersecting runways, as both increase the capacity of an airport in the long-run but not necessarily in the short-run. The reasoning behind this argument is the fact that the geometric configuration of the new runway, relative to other elements in the airfield, will determine if it can be used independently or not. The distance between the centerlines of two runways is the key parameter to determine if simultaneous operations can be performed under a given set of operating conditions (i.e. whether instrument or visual flight rules are being used). Even if a close parallel runway is built where completely independent operations cannot be performed, the capacity of system will increase as the traffic may be segmented between the two. For example, one of the runways can be used for take-offs while the other can receive landings resulting in a more efficient operation and higher throughput.

In airfields without a dominant wind direction, it may be necessary to build runways with different orientations to sustain operations under crosswind conditions. Aircrafts usually perform their take-off and landing maneuvers with headwind (i.e. the aircraft blows against the direction of travel) with the purpose of reducing the distances required as the wind generates part of the required lift. However, the wind direction is not always as stable as airport operators prefer and it may change considerably during the day. In airfields where crosswind conditions are usual, it is common to find intersecting runways in the predominant wind directions. Even though the simultaneous use of intersecting runways is a higher logistical challenge when compared to parallel systems, a new intersecting runway increases throughput in the long-run as the airport will be able to operate in a higher number of wind scenarios.

Another strategy to increase the throughput of a runway system in the long-run is investing in Instrument Landing Systems (ILS) that extend the operating capability in adverse meteorological conditions. ILS transmit radio signals to guide the approaching aircraft with horizontal and vertical information and is usually complemented by high-intensity runway lights. Five categories of ILS exist (CAT I, II, IIIA, IIIB, and IIIC) with descending visibility requirements and ascending capital costs. The economic analysis to determine the ILS category in which to invest will weigh the recurrence of poor-visibility conditions and the increase in utilization of the infrastructure.

5.4.2.2 Location

The location of elements in an airfield can be strategically influenced to increase its throughput. As mentioned previously, the layout of different elements has the potential of considerably expand the capacity of a runway given that an efficient design is implemented. However, the expansion of the elements of the airside is constrained by the separation between elements that guarantee safe operations, as elements designed for different aircraft require distinct separations between elements.

5.4.2.3 Function

The function of the airside of an airfield (understood as the type of aircraft that it can serve) can be intervened in two main ways: by modifying the cross section of the elements or by introducing longitudinal expansion into the system.

The cross-section of an airside element (runways, taxiways, high-speed exits, taxi lanes, and aircraft stands, etc.) is determined by the size of the aircraft that it is intended to serve. This implies that larger aircraft will require wider pavement structures that will have wider spaces between them. Therefore, a Strategic Plan of an airport will consider possible expansions from the outset avoiding constraints on future developments: even though it might not be necessary to build all the pavements up to Code Letter F (largest wide-body aircraft: A380 and B747), it is important to guarantee the separation between centerlines of the highest category expected to guarantee the viability of upgrades in the future.

In terms of length of elements, a distinction can be made between runways and other pavement structures in the airfield. The length of a runway is determined by the field length (take-off distance) that the design aircraft requires under the physical and meteorological conditions of the aerodrome. As a general rule, larger, heavier aircraft will require longer runways. An initial design for an airdrome may contemplate the possible expansion of runways if there is an upgrade in the aircraft that the airport is serving. Other pavement structures are usually laid out with the objective of supporting runway operations in the most efficient way. Therefore, the construction of additional taxiways and taxi lanes will be a function of the demand of existing runways and how airfield planners design efficient connections with new runways.

5.4.3 Airport Landside

An airport's landside refers to the areas that are not devoted to the operation of aircraft (airside). The main structures are the passenger terminal and parking buildings. The expansion of these facilities is usually performed horizontally, as the vertical dimensioned is constrained by obstacle limitation surfaces around the runways.

5.4.3.1 Capacity

The expansion of landside capacity can occur at two different scales and in any case is limited to its boundaries. An airport can increase the number of passengers it can process per unit of time with strategies that include the internal reorganization or expansion of terminal spaces and the construction of new terminals.

It is convenient that the initial design of an airport terminal contemplates the possibility of its expansion. For this reason, a Strategic Plan will contemplate the intervention of facilities and will guide the design so that the addition of new areas is simple and cost effective. For example, it is advisable to avoid the construction of load-bearing walls in places where possible expansion is foreseen.

The second scale at which the expansion of the landside capacity can happen is the construction of new terminals. The complexity of this type of intervention is much greater and depends on prior planning. The design of new terminals should tend for a high flexibility to handle the different types of flows that an airport can receive, as previously mentioned.

5.4.3.2 Location

The construction of new terminals, in a similar way as the construction of new runways, will be simpler when they have been considered early in the planning process and the land is available to do so. A strategy to do so is land banking, where the land is taken out of the market and reserved for future expansion. It is common for Airport Master Plans to contain considerations in relation to possible areas of expansion.

5.4.3.3 Function

Different flows within an airport (i.e. departures and arrivals, domestic and international passengers) must be handled in different ways to ensure the efficiency and safety of the airport operation. It is common for terminals to be designed with clearly defined flows in order to isolate those types of traffic that require special treatment as, for example, international arrivals must pass through border control in most countries. Introducing flexibility in the technical design of the terminals is an efficient strategy to accommodate changes in the distribution of traffic types over time. If an airport loses international relevance, a flexible design will allow it to efficiently accommodate national traffic and avoid the obsolescence of its facilities. This can be achieved through swing gates, holding rooms, and corridors within the building that allow the isolation of the different flows as necessary.

The landside of an airport must be prepared to accommodate changes in the composition and characteristics of the aircraft mix. Terminals must be able to efficiently manage the flows derived from changes in the capacity of airplanes without becoming operating bottlenecks. For example, it may be useful to have the flexibility to direct more than one jet bridge to the same aircraft, in the

case of widebody aircraft with capacity in excess of 300 people. This will accelerate the ground handling of aircrafts and will allow for a higher utilization of gates.

Similarly, as an airport receives a greater number of passengers (regardless if it is caused by an increase in the number of aircraft or a shift towards airplanes with higher passenger capacity), the associated service areas and facilities must be adjusted accordingly. This is why waiting areas, baggage handling facilities, and commercial services should be adapted as traffic changes with the purpose of ensuring operating efficiency and passenger satisfaction.

5.4.4 Water Treatment Plants

This section will refer to the treatment of potable and waste water. Although the final product is different in terms of use and quality, pragmatically the same objective is sought: removing contaminants present in the liquid through a series of physical, chemical, and biological processes. Despite the clear trend of population growth and its relationship with water consumption that suggest that the demand for potable water and the production of wastewater will continue to grow in the near future, the phenomenon of climate change has the potential to change the patterns of water use in the medium and long term. For this reason, introducing technical flexibility within treatment plants is prudent as it allows the system to be adjusted at the lowest possible cost.

5.4.4.1 Capacity

The uncertainties that water treatment plants face imply that the volumes, concentrations, and conditions of the inflows are not known in advance and may vary considerably. In the case of increases in the inflow, it is advisable to design a modular system that can be expanded as its capacity is reached and more information is acquired regarding future requirements.

5.4.4.2 Location

Within the treatment plant and under a modular design, there is flexibility to locate and reorganize the different systems as appropriate. The principle should be to avoid pumping water as much as possible so that most of the flow is by gravity.

5.4.4.3 Function

In terms of function, it is very important that water treatment plants have the flexibility to extend the spectrum of their treatment to more complex contaminants or higher removal levels. The addition of modules that allow secondary and tertiary treatments is advisable which is why it is important to design the systems with the capacity to accommodate them. As a result, the systems could be adapted to changing conditions of concentrations, pollutants, and environmental policies in the most cost-effective way.

5.4.5 Social Infrastructure

As mentioned in Chapter 2, social infrastructure encompasses the services required for a nation's human development. It includes services related to healthcare, education, prisons, and governmental operations. For the purposes of this document, social infrastructure services are provided in enclosed structures that consist of walls and a roof, with technical specifications that may vary depending on the type of service provided. As a result, the following analysis is applicable to healthcare facilities, schools, governmental office space, and parking structures.

5.4.5.1 Capacity

The expansion of capacity in social infrastructure buildings can happen horizontally or vertically. While horizontal expansion might be less capital intensive and complex from a technical point of view, it is curtailed by the boundaries of the project. For example, a hospital complex can only expand within its limits. In the case of vertical expansion, the constraints to expansion are dictated by zoning ordinances and the design of the initial phase (and its capacity to bear additional loads).

5.4.5.2 Location

The flexibility in terms of location for social infrastructure services has a huge potential. If a SPV has been mandated to provide health care, education, or penitentiary services without reference to specific sites, managers can strategically locate their facilities for a more efficient service provision. The public's access to public services can be advanced by dispersing social infrastructure facilities within a territory instead of concentrating the provision of the service in a single facility. For example, a network of health care providers can be created by building urgent and primary care facilities in strategic locations. These facilities will provide the most common and basic services, will triage complex cases, and determine the need for transfers towards hospitals or advanced care facilities.

5.4.5.3 Function

Flexibility in terms of function is very important for social infrastructure, as the nature of the services to be provided may change with time. As a result, designs that do not curtail future changes in uses should be considered. For example, education in the future might trend towards classes with more students than nowadays. Given this uncertainty, it is not advisable to have load-bearing walls as partitions between classrooms as expansion will not be easy (if not impossible). A system of moment-resisting frames provides a higher degree of flexibility for internal reconfiguration of spaces.

5.5 Financial implications of Technically De-risked PPPs

Introducing technical flexibility in PPPs should increase their bankability, as the valuation of projects features higher expected values, lower capital expenditures at the outset, and reductions in the values at risk. Flexible design alters the risk profile of projects -- reducing the downside and increasing the upside -- and lower risk implies lower interest rates and easier financing. Additionally, flexible engineering incentivizes managerial proactiveness to exploit the available optionality. As projects are phased and the initial stages are small, managers are encouraged to constantly monitor the market to better cater to users.

Flexibility provides an effective tool to manage demand risk while mitigating the distortions and perverse incentives that credit enhancement measures might introduce. The existence of guarantees numbs the incentive for flexible developments and creates opportunities for moral hazard, adverse selection, and exploitation of information asymmetries. For example, when minimum revenue guarantees are in place, the concessionaire has the incentive to build bigger as the investments would be covered in case of revenue shortfall. As a result, flexibility then can help in achieving a *purer* form of PPPs, where commercial risk is transferred in a higher percentage to the private sector while reducing the size and need for credit enhancements.

It is sometimes argued that demand risk should be shared between the public and private sectors, as the concessionaire does not possess the tools to adequately manage it. This document shows the opposite, as the engineering design of the physical infrastructure can be used strategically to better accommodate different futures.

The life cycle approach of PPPs – focused in outputs and not inputs, on service provision and not asset construction, where risks and responsibilities are transferred – is the perfect setup for the development of flexible infrastructure projects. As long as the Key Performance Indicators of the contract are met, the concessionaire is free to define how much it deems fit to invest. The concessionaire then has the incentives to actively manage demand and credit risk by adapting the system as new information arises.

5.6 Conclusion

This chapter demonstrated how the concept of Flexibility in Engineering Design can be applied to infrastructure projects. By phasing the construction of the assets, infrastructure PPPs can be considerably de-risked and future-proofed. This concept has the potential of unlocking the full potential of PPPs by more efficiently allocating demand risk between parties and accessing lower financing rates.

The Unites States provides a very interesting case study of risk transfer. By partnering with airlines, airport authorities have been able to transfer demand and credit risk to a higher extent and increase the cost effectiveness of capital expenditures and operations. The following chapter explores this model.

Chapter 6

AIRLINE INVOLVEMENT IN AIRPORT DESIGN

6.1 Introduction

Many models exist for involving the private sector in airport development. Ranging from traditional public procurement to complete privatization, the available models set the public interest at their center given a public service understanding of air transportation. The United States have used a particular approach that gives airlines a special treatment: they can influence the design of the infrastructure, share the revenue, and obtain better financing conditions in exchange for assuming demand risk.

The effects of airline involvement in airport development is explored, as it can be documented from the experience of airports in the United States. The main idea is that airlines will promote architectonically simple but high-efficiency facilities, especially when they are sharing or completely responsible for demand risk. The design of various airport terminals across the US will be compared to iconic terminals in Europe to support this argument.

The prevailing approach in the US is compatible with the idea of de-risking infrastructure projects and increasing their bankability through flexible engineering design. Given the high dynamism of the air transportation industry, long-term forecasts for airport planning will most certainly be 'wrong'. Therefore, a flexible, staged approach to airport and terminal development is a technical risk-hedging mechanism the decreases downside exposure and increases upside opportunities. A flexible design will facilitate the deal's bankability due to a lower value at risk under unfavorable conditions.

The successful de-risking of US airports will be presented in the study of 'dehubbed' airports – which have faced important market downturns. The chapter concludes with suggestions about how the use of flexibility in design could be implemented to de-risk airports and increase their bankability under uncertain conditions, as a complement to the recommendations provided in Report 76 of the *Airport Cooperative Research Program*. Of particular relevance is the importance of a collaborative process that involves airport authorities, airlines, and financiers in order to better exploit the opportunities that airport development offers.

6.2 Effects of Sponsors' Incentives in Airport Design

Lim (2008) describes in his book *Creating paradise T3: Singapore Changi Airport* the process and motivations that led to the construction of one of the most ambitious airport terminals of the moment. Mr. Lim describes how T3 was a "chance for CAAS (Civil Aviation Authority of Singapore) to create a terminal that would offer a level of service that was better than T1 and T2; to have T3 carry the Changi torch in the airport's race to stay the best airport in the world", showing clearly that the motivation for the new terminal was maintaining the status of Changi. Additionally, the idea was that "T3 (would) become a destination in itself" as a "showpiece terminal to wow the world." To achieve this goal, "familiar structural concepts had to be dropped to achieve the ambitious level of physical transparency desired for T3" due to the amount of floating glass panes the compose the façades to achieve an effect of weightlessness and transparency.

In the vast main hall, the architects decided to include voids that would accentuate the vastness of the construction. They acknowledge that "there is a price for making these voids, but the opportunity cost of losing valuable floor space that could be leased out commercially is offset by a richer and more complex spatial experience that makes the T3 environment unique." On the other hand, "increasing the floor-to-floor height was out of the question, as a level of the departure governed by 6-metre-high datum floor was desired." All these measures were part of a strategy to achieve the target Level of Service which, as stated by Mr. Lim, could not be less than the 'A' standard.

The situation just described is not uncommon. This narrative usually accompanies the design of majestic airport terminals by 'starchitects'. They are chartered by governmental authorities to create the gateways to countries and regions: symbols and measures of economic success and development (Sommers and Fentress Bradburn Architects Ltd., 2000). To Binney (1999), "terminals have become more important these days than cultural places such as museums or theatres where societies used to assemble." As Thomas-Emberson (2007), describes it, "airports have now become temples to travel." However, he recognizes that politics has been one of the main drivers, leading to famed architects creating the most unusual shapes and forms.

It is clear then that the incentives at play during the procurement of the design and construction of a new passenger terminal building (PTB) define the grandiosity of the result. A government that intends to send a statement will probably invest more in achieving a design that inspires awe, while performing the provision of aeronautical services loses prominence. However, the cost effectiveness of a monument will be lower given that there is a much higher cost involved in providing the same benefits that a simpler design would provide, ceteris paribus. Higher capital investments are directly proportional to operating expenditures, debt service requirements, and susceptibility to swings in the expected income stream. A higher exposure to demand risk caused by non-technical motivations will exacerbate the consequences of economic downturns and project specific challenges.

Despite the pervasiveness of these circumstances, it can and has been done in a different way. A design process driven by the bottom line will promote austere facilities with high operating efficiencies. All other conditions kept equal, a simpler and less costly PTB design will result in a lower exposure to demand risk and project specific challenges than a more convoluted alternative would. In the case of airports in the United States, whenever airlines are part of the planning and decision-making process, they will shape it towards highly cost-effective designs. Therefore, airlines can technically de-risk airport infrastructure by reducing its sensitivity to adverse conditions.

This de-risking effect of airline involvement in airport planning and design exploits the flexibility that airports offer, as passenger buildings and many other airport facilities can easily be designed and implemented in modules. This modularity will be a function of how intricate and reproducible the design is, with a tight connection to economies of scale. A trade-off between the efficiencies that might be attained by constructing bigger facilities in one go and the benefit of not committing to a given design must be made.

There is one caveat: the hypothesis of this document is based on the overall trend observed in airport PTB design. Exceptions will exist as airport development occurs in a social context with multiple dimensions to consider.

6.3 Airport Development in the United States

In 1996, the Federal Aviation Administration (FAA) launched the Airport Privatization Pilot Program (APPP) to explore private involvement in an infrastructure type that has historically been under public control. The pilot opened ten 'slots' for airports with different characteristics and, as of April 2017, only the Luís Muñoz Marín International Airport in Puerto Rico had been approved (FAA, 2018). Given the central role that the Trump Administration's infrastructure plan assigns to private investment, there is a growing interest in the widespread implementation of airport Public Private Partnerships – PPPs.

Private involvement in the ownership or management of US airport operations is not common. A vast majority (98%) of 3,300 airports are owned by public entities (FAA, 2013). In comparison, 47% of airports in the European Union have some sort of private involvement with 17% being completely private (ACI Europe, 2016). Despite these numbers, airports in the United States show a very high involvement of private parties in different aspects of everyday operations, in some cases resembling PPP arrangements.

The United States have a tradition of clearly defining the rules of engagement between airports and airlines in legally binding contracts (Graham, 2014). Of particular interest are the Airport-Airline Use and Lease Agreements, a contractual arrangement that defines the rights, responsibilities, and

limitations of both parties throughout its term (Transportation Research Board, 2010). These agreements share some characteristics with the PPP framework previously described: they exhibit long-term characteristics related to the provision of a public service, they define the methodology under which airport rates and charges are set, there is a de facto bundling of design and operations, and operating efficiency is incentivized. Additionally, they define the demand risk distribution among the parties involved following two main models (or a hybrid between the two):

1. In a residual agreement, airlines agree to pay any costs of running the airport that are not allocated to other users. Demand risk is transferred to the airline as it will have to pay the shortfall if the airport's revenue does not cover its costs.
2. In a compensatory one, the airport operator assumes the major financial risk of running the airport and charges the airlines only for their share of costs.

Airlines operating under residual agreements assume a very high portion of the demand risk, to the extent that these agreements are often used as guarantees for bonds that finance airport expansion. General Airport Revenue Bonds issued for such purpose and backed by a 'signatory airline' result in more competitive interest rates (Xiao, Fu and Zhang, 2016). In reciprocity, it is common that the signatory airline acts as the Majority in Interest (MII) to which the airport operator must consult before proceeding with capital investment plans. This structure closely resembles the characteristics of public-private partnerships where risks are transferred from the public to the private sector. In contrast, the public entity retains its exposure to demand risk under a compensatory scheme.

Under compensatory regimes, the airport operator retains demand risk and charges the airlines for the costs that they incur. This type of agreement provides a higher degree of freedom to the operator in deciding the peculiarities of the capital investment program with the trade-off of losing the financial guarantee provided under the residual approach. Nevertheless, the incentives to invest and operate efficiently still exist in a competitive airport environment (Transportation Research Board, 2010). If the airport is over built, it can become too costly for airlines which might reduce air service. On the other hand, if it does not keep up with demand delays might also deter operations due to inefficiencies and losses in revenue. Therefore, it is in the operator's best interest to provide the adequate level of capacity in the most cost-effective way possible.

6.4 Managing Demand Risk in US Airports

Given the services that they provide and how they enable economic activity and development, it is common that infrastructure projects are of strategic importance for governments. Projects with negative financial net present values (NPVs) can have positive economic NPVs given the spillover effects on society and the economy. While pursuing policies and development plans, governments often provide sovereign guarantees to enhance the credit profile of a project and facilitate its bankability. These guarantees usually provide an insurance against shortfalls in revenue collection,

i.e. demand risk. Governmental guarantees can be explicit (where terms and conditions are clearly stated in a contract) or implicit, when the strategic value of a project and the political cost of its failure are such that officials will not let it fail.

When sovereign guarantees are present in a project (disregarding their taxonomy) it can be said that demand risk is shared with the private party. Creative formulas have been enacted in different infrastructure contracts to define the proportion of risk that each party will bear. Unfortunately, neither the operator nor the government can do anything significant to increase demand for air services beyond creating an incentive scheme to attract airlines. If unsuccessful, the ultimate effects of insufficient revenue will be borne by taxpayers.

Now, when demand risk is transferred to airlines as is usual in residual schemes, an incentive to increase air service is created. Among the considerations of the signatory airline for bearing risks are lower aeronautical charges, varying degrees of influence over airport planning, operations and capital expenditures, and exclusive or preferential use of facilities in some cases (Fu and Yang, 2017). It is in the airline's best interest to utilize existing capacity as much as possible, as it will have to cover shortfalls in revenue. Therefore, airlines can effectively influence the demand profile of an airport and be the factor that decides whether it will succeed or fail.

The Airports Council International reported that 12 out of 26 large hubs in the United States operate under a form of residual agreement, while 10 under a compensatory one (ACI NA - Airport/Airline Business Working Group, 2018). It is interesting how almost half of US Large Hubs operate in a scheme that assigns an important portion of demand risk to a private party and, in consequence, receives a determinative input from it.

6.4.1 Airport Revenue Bonds

Moser (2015) identifies the generous federal tax subsidy provided to the robust municipal bond market as one of the main barriers for the ubiquitous implementation of the PPP model in the United States. There is a great variety of airport bonds that airport authorities can issue to fund capital investments (Transportation Research Board, 2007):

- General Obligation - GO Bonds backed by general tax revenue of the local government (city, county or state) that owns the airport.
- General Airport Revenue Bonds - GARBs backed by airports' general revenue (the most common type of airport development bonds).
- Passenger Facility Charge - PFC Bonds backed by airports' future PFC revenue (i.e. additional fee charged per passenger).
- Customer Facility Charge – CFCs Bonds backed by airports' future CFC revenue (e.g. fees paid by rental car customers).

- Special Facility Revenue Bonds – SFRBs, whether the facilities will be used by a single tenant or multiple tenants.

SFRBs are the instrument by which demand risk is transferred to the signatory airline(s) that will benefit from the bond issuance. In exchange for the absorption of demand risk and 'unconditionally guaranteeing' the bond repayment, it is common that the airline(s) is(are) granted special easements and rights related to operating charges and development decisions.

However, GARBs also introduce an incentive to create efficient and commercially viable designs due to the autonomy of airport authorities in the United States. As the regulatory framework does not consider sovereign guarantees or governmental grants to bail out an inefficient administration, efficiency and effectiveness are fostered. This corporatization of the airport authorities promotes a risk-adjusted provision of capacity with embedded options that facilitate expansion or modification of use.

6.4.2 Examples of Special Facility Revenue Bonds

The City of Houston issued in 2018 $138 million in tax-exempt Special Facility Revenue Bonds to finance the construction and acquisition of certain special facilities to be used by United Airlines. As the bond statement defines it, these bonds are payable solely from and secured by the net rentals to be paid by United for the use of said facilities. These bonds are unconditionally guaranteed by United and shall never constitute an indebtedness of the City. The maturity of the bonds issued is 35 years and are subject to earlier termination upon an event of default (City of Houston, 2018).

The City will also grant to United, under the Special Facilities Lease, certain easements that are related to the use of the facilities and certain rights to certain additional facilities improved in connection with the construction of the Special Facilities which are occupied by the City and not leased to United. Additionally, the costs of constructing administrative and engineering space and parking spaces at the technical operations center project site at the Airport to be used by United for company-wide functions not related specifically to United's operations at the Airport will be paid directly by United (City of Houston, 2018).

The bond statement includes a description of the airline and its current financial situation. It also provides a very thorough recollection of the risks to which United is exposed to, while stressing the fact that a potential default of the airline will never constitute an indebtedness of the City of Houston. Therefore, the risk that revenues are not sufficient to amortize the bonds is completely transferred to United which will be liable for any default.

A Special Facilities Revenue Bond like the one just described is a rather peculiar case of risk transfer in the context of airport development. Given its unconditional guarantee on the repayment of the bonds, United will design the new facilities in such a way that they provide the highest value for

money (or cost-effectiveness) to support its ongoing operations. It is United's best interest that the facilities that are built do not display an excess of capacity and that a right balance between capacity and potential demand is achieved. Accordingly, United will be interested in facilities that include technical flexibility that will facilitate expansion when and if capacity is insufficient to provide adequate levels of service. Such a trigger for investment will be an indicator that the expected use of the facility was achieved and surpassed and will probably be tied to similar financial results.

Even if a similar agreement is not in place, the main consequences of it can be replicated in the planning and design of new PTBs. Flexible, cost-efficient designs that respond mainly to technical and operating requirements will reduce the exposure to demand risk and swings in market conditions.

6.5 Practical Implications of Use and Lease Agreements

The bottom-line focus in airport planning caused by airline involvement results in the construction of facilities with a higher cost-effectiveness, higher operating efficiencies, and less risky investments. The United States is a showcase for architectonically simple but highly efficient passenger terminal buildings, when compared to other mature markets. For example, the 2018 list for the World's Top Airports as voted by international air travelers[4] ranks the Denver International as the first airport in the US but positioned as 27 in the list. These results suggest that US airports are not highly regarded by international air travelers.
APPENDIX A provides a comparison of PTB design for 5 renowned airports in the United States and the European Union. A stark contrast surfaces between simple designs that can easily be replicable or modified and signature roof lines, intricate structures, and one-of-a-kind designs.

However, US airports have shown high resilience after the deregulation of the industry. Default studies by the three major rating agencies indicate that there has not been a default on a General Airport Revenue Bonds issued by a major commercial airport in the United States (ACI NA, 2011) while more than 200 airlines have filed for bankruptcy since 1978 (Airlines for America, 2018).

[4] "The 2018 Awards are based on 13.73 million airport survey questionnaires completed by over 100 different nationalities of airline customers during the survey period. The survey operated from August 2017 to February 2018, covering 550 airports worldwide and evaluating traveler experiences across different airport service and product key performance indicators - from check-in, arrivals, transfers, shopping, security and immigration through to departure at the gate. The Survey was available in English, Spanish and Chinese language options" (Skytrax, 2018).

Table 4 The World's Top 60 Airports (Skytrax, 2018)

The World's Top 100 Airports - 2018		
Rating	Airport	2017 Rating
1	Singapore Changi	1
2	Incheon	3
3	Tokyo Haneda	2
4	Hong Kong	5
5	Doha Hamad	6
6	Munich	4
7	Centrair Nagoya	7
8	London Heathrow	9
9	Zurich	8
10	Frankfurt	10
11	Tokyo Narita	14
12	Amsterdam	11
13	Kansai	12
14	Vancouver	13
15	Taiwan Taoyuan	21
16	Helsinki	17
17	Vienna	24
18	Shanghai Hongqiao	18
19	Copenhagen	15
20	Sydney	23

The World's Top 100 Airports - 2018		
Rating	Airport	2017 Rating
21	Cape Town	19
22	Brisbane	16
23	Dubai	20
24	Auckland	22
25	Hamburg	27
26	Durban	35
27	Melbourne	30
28	London City	36
29	Denver	28
30	Dusseldorf	40
31	Cologne / Bonn	29
32	Johannesburg	37
33	Beijing Capital	25
34	Cincinnati	26
35	Haikou	48
36	Bangkok Suvarnabhumi	38
37	Paris CDG	32
38	Xi'an	45
39	Athens	53
40	Gimpo	47

The World's Top 100 Airports - 2018		
Rating	Airport	2017 Rating
41	Toronto Pearson	43
42	Barcelona	33
43	Madrid	31
44	Kuala Lumpur	34
45	Jakarta	44
46	Bogota	42
47	Quito	52
48	Houston Intercontinental	54
49	Lima	55
50	Atlanta	41
51	San Francisco	39
52	Christchurch	61
53	Abu Dhabi	49
54	London Gatwick	51
55	Gold Coast	50
56	Dallas/Fort Worth	46
57	Lisbon	68
58	Stockholm Arlanda	62
59	Perth	71
60	Chengdu	56

In the last 3 decades, various US airports have been "dehubbed". Among them, Raleigh–Durham International Airport (RDU), St. Louis Lambert International Airport (STL), Pittsburgh International Airport (PIT), Cincinnati/Northern Kentucky International Airport (CVG), and Memphis International Airport (MEM). These airports experienced dramatic reductions in traffic after an airline with significant market share scaled-down or withdrew air service (see Figure 1). The causes range from bankruptcies, economic downturns, or simple strategic decisions. Most of these airports are still struggling to attract air service.

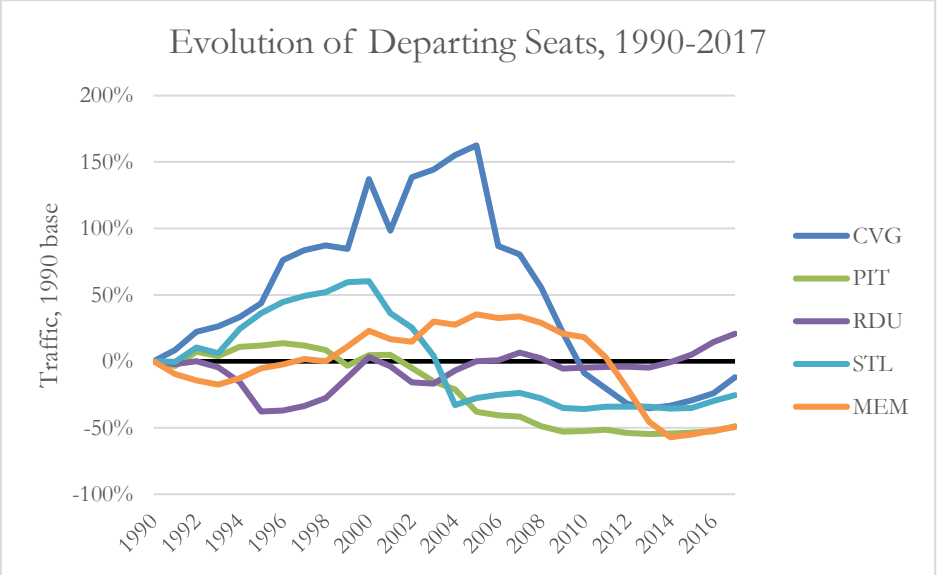

Figure 15 Evolution of departing seats for "dehubbed" airports, 1990-2017 (OAG, 2018)

6.5.1 Raleigh–Durham International Airport

In 1987, American Airlines opened the new Terminal C of Raleigh–Durham International Airport (RDU) to concentrate its north-south hub operations there. Thanks to it, traffic increase from 1.4 million departing seats in 1985 to 4.7 million in 1990 – a 335% growth (Raleigh-Durham International Airport, 2018). Given the difficulties presented in competing with USAir's hub in Charlotte and Delta's hub in Atlanta, American started to downsize its hub operations at RDU in 1993 and ceased in 1996 the majority of its mainline flights (Raleigh-Durham International Airport, 2015).

As with Concourse C of CVG, Terminal C of RDU was financed through $113 million in special facility revenue bonds unconditionally guaranteed by American (Sun Sentinel, 1997). To avoid paying for facilities that it did not intend to use, it started subleasing its gates to Midway Airlines in 1996 which explains the first recovery in traffic presented in Figure 16. Midway filed for bankruptcy after the 2001 terrorist events in the US and ceased operations in 2002 (Encyclopedia of Chicago, 2005). After 2001, traffic recovered thanks to new air service from low cost airlines and other legacy carriers. The great recession resulted in a new reduction in traffic which was recovered in subsequent years.

In 2007, RDU issued $153 million of Airport Revenue Bonds to construct a new Terminal C that would triple the size of American's facilities. This issuance was well received by credit rating agencies with an Aa3 rating from Moody's and an A+ from Fitch (Raleigh-Durham International Airport, 2007). Not only was RDU able to manage successive downturns thanks to the risk distribution defined in its Use and Lease Agreements, but it was able to maintain an investment grade throughout these years.

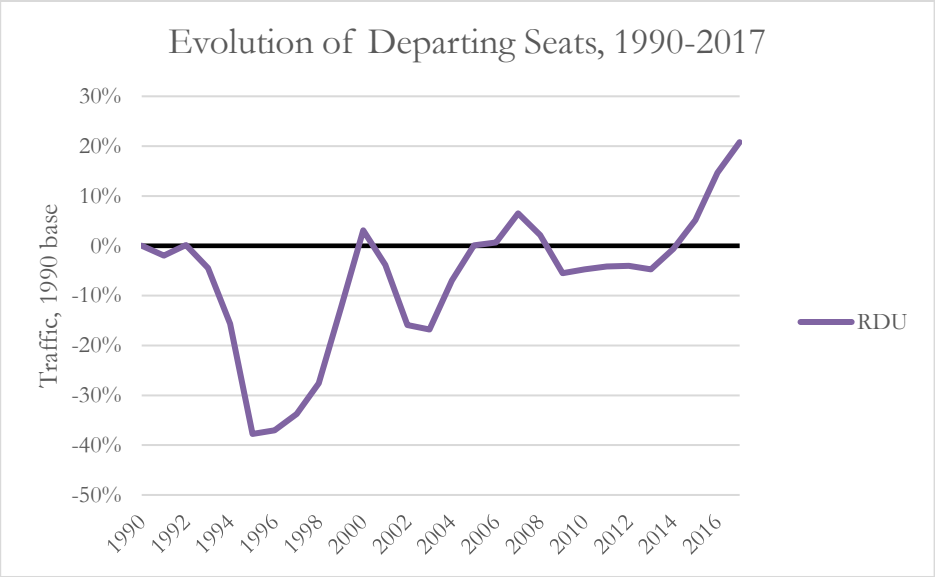

Figure 16 Evolution of departing seats at Raleigh–Durham International Airport, 1990-2017 (OAG, 2018)

6.5.2 St. Louis Lambert International Airport

Trans World Airlines (TWA) operations in St. Louis Lambert International Airport were strong since 1985, reaching 10 million departing seats in 1990. In 1992 the airline filed for bankruptcy and moved its headquarters to STL in 1993 as part of an agreement with the city given the outstanding bond issuance with TWA's assets as collateral (UPI, 1993). The consolidation of TWA's operations in STL led to a significant growth in traffic, reaching 16 million departing seats in 2000. Regardless of this, TWA filed for bankruptcy again in 2001 and was purchased by American Airlines for $742 million (Los Angeles Times, 2001).

American planned for STL to become a reliever hub for its main hubs at ORD and DFW. The nationwide recession of the dot com crisis and the effects of the terrorist events of 2001 made this move unnecessary, further decreasing the strategic need for Lambert (Travel Weekly, 2003). As a result, the airport experienced a 58% reduction in demand between 2000 and 2004 with 6.7 million departing seats scheduled in the latter. Growth started to slowly recover until 2008, when the great recession caused American to close its hub in STL (USA Today, 2011). Southwest's expansion acted as a palliative and kept the airport afloat.

In 2009, STL issued $130 million in General Airport Revenue Bonds to support the renovation plan known as "The Airport Experience Project" (City of St. Louis, 2009). The bonds were rated as A3 by Moody's and A- by Standard & Poor's, both with stable outlook, a clear signal of the financial health of the airport (Airport Improvement, 2015).

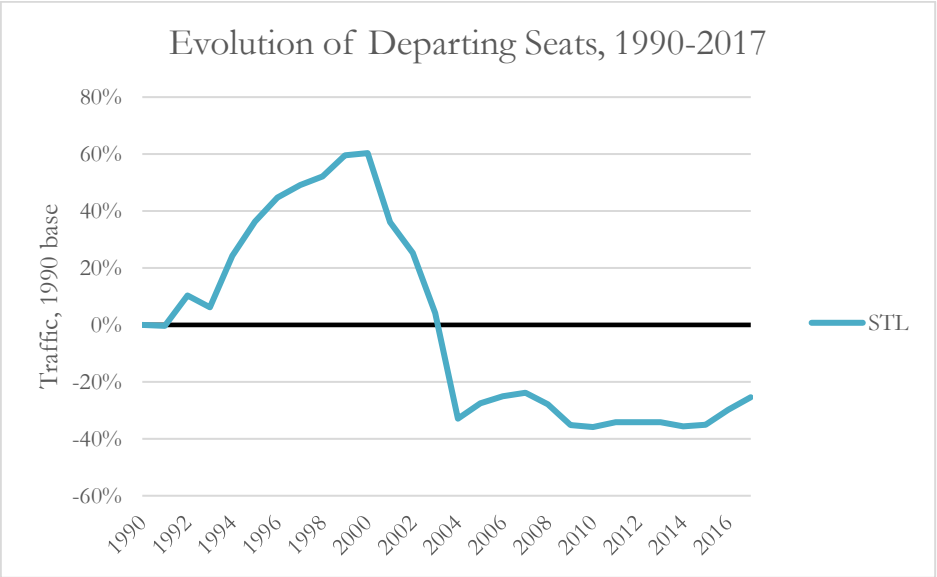

Figure 17 Evolution of departing seats at St. Louis Lambert International Airport, 1990-2017 (OAG, 2018)

6.5.3 Pittsburgh International Airport

In 1992 the Allegheny County airport authority issued bonds worth $650 million to be invested in a 2.1-million-square-foot terminal backed by the operations of US Air for Pittsburgh International (New York Times, 2004). The terminal pioneered the commercially focused concept of modern passenger buildings at a moment when traffic in the airport was around 9.1 million departing seats. It would reach its peak at 9.7 million departing seats due to strong hub operations by the airline in the nineties.

The terrorist events of 2001 plus high operating costs at the airport (due to the outstanding debt) accentuated a decline in traffic. In 2004, US Airways announced that its hub operations at PIT would cease at a moment when a third of departing seats had been lost (USA Today, 2007). With 6.7 million departing seats in 2004, the traffic decline was exacerbated by the Great Recession down to 3.9 million departing seats in 2012. Since then, traffic has stabilized thanks to the rise of other carriers' service to the airport – mainly ULCC's and Southwest (NBC News, 2011).

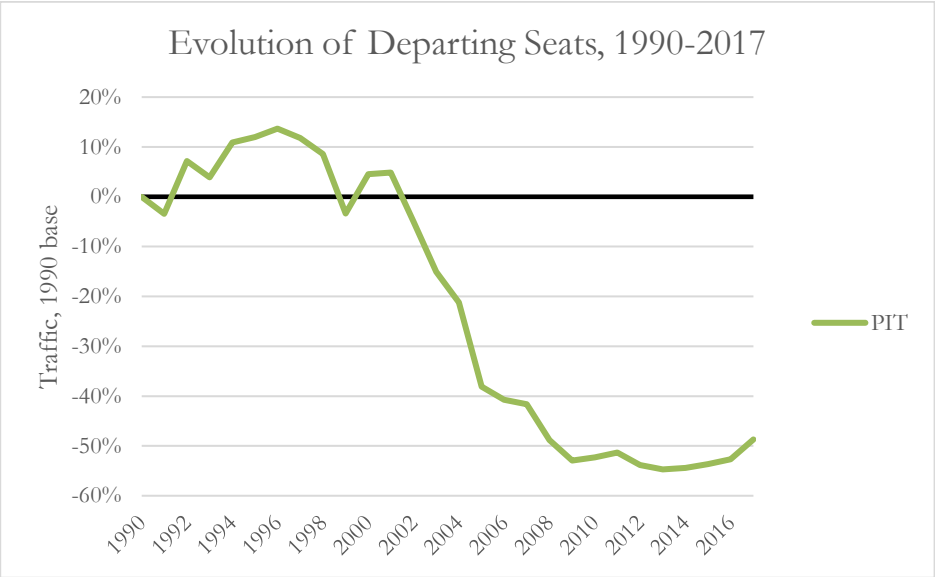

Figure 18 Evolution of departing seats at Pittsburgh International Airport, 1990-2017 (OAG, 2018)

6.5.1 Cincinnati/Northern Kentucky International Airport

In 1994, Delta and Cincinnati/Northern Kentucky International Airport (CVG) inaugurated the $50 million Concourse C designed to serve 50-seat regional jets. Its 48 gates were used by Delta's regional operations (Comair) and were essential to CVG's fast growth (Cincinnati Inquirer, 2016). This resulted in a traffic increase from 4.3 million departing seats in 1990 to 11.4 million departing seats in 2005. By that time, CVG was Delta's second largest hub after Atlanta, and the fourth largest hub worldwide for a single airline.

However, Delta's bankruptcy in 2005 led to a dramatic reduction in flights to/from CVG (ABC News, 2015). In terms of departing seats, the offer went from 11.4 million in 2005 to 8.1 million in the following year – a 29% reduction. Given that hub and spoke operations were responsible for CVG's growth and connectivity, reductions in service had a much more dramatic effect in the airport's attractiveness as a connecting hub. A combination of the increasing fuel prices, the great recession, and Delta's acquisition of Northwest Airlines gave way to further air service reductions (Associated Press, 2010). In 2010, Delta decided to cease operations in Concourse C. By 2013, departing seats in the airport were below 1990 levels (2.8 million vs 4.3 million) and translated in a 75% decrease from its peak in 2005.

The construction of Concourse C and its subsequent lease to Delta was the result of a use and lease agreement where Delta was committed to lease payments until 2025. This feature of the agreement was an effective risk transfer from the airport bond issuer to the airline, guaranteed the bond repayment, and avoided the bonds' default. In 2016, the contract was renegotiated and the concourse demolished to create a site for parking and deicing planes (Cincinnati Business Courier, 2016).

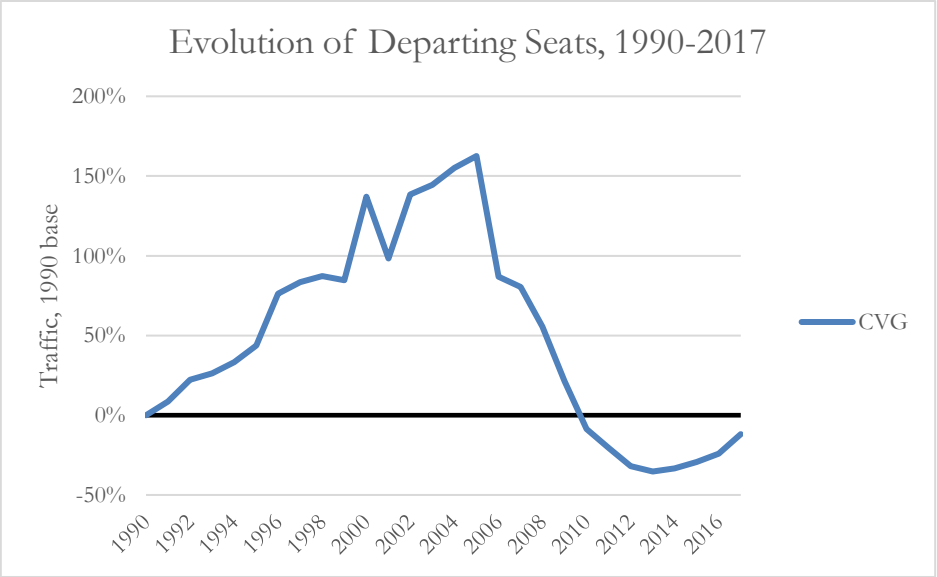

Figure 19 Evolution of departing seats at Cincinnati/Northern Kentucky Airport, 1990-2017 (OAG, 2018)

6.5.2 Memphis International Airport

After a slight decline in traffic, in 1992 Memphis International Airport (MEM) started a steady growth from 3.6 million departing seats up to 5.2 million in 2000 as one of the primary hubs for Northwest Airlines. The events of the dot com economic crisis and the terrorist attacks in the country's northeast did not prove to be as devastating, where MEM hosted 5.7 million departing seats in 2007. However, the announcement of the merger between Northwest and Delta in 2008 resulted in a reduction of passenger flights in MEM, as it is located about 400 miles from Delta's main hub at Atlanta (USA Today, 2013). In 2013 Delta decided to cut hub operations at the airport resulting in a historic low of 1.8 million departing seats in 2014. The airport has not been able to recover much of its previous passenger traffic despite an intense marketing campaign and the arrival of ULCCs (New York Times, 2018).

Despite the suboptimal use of the existing passenger infrastructure in the landside of the airport, the airside has not been unused at all. Memphis International was for many years the airport with the largest cargo operations of the world, only until Hong Kong surpassed it in 2010 (Travel Codex, 2018). This feature of the airport can be understood as the decision to diversify the services provided by the airport in markets that are not perfectly correlated. As passenger and cargo air traffic do not respond to the same stimulus and economic events, the airport has been able to stay afloat thanks to FedEx's operations. Of the three concourses that were used in its moments of former passenger glory, MEM has consolidated operations in Concourse B and mothballed A and C with the option of reopening them if demand is high enough (Daily News, 2018).

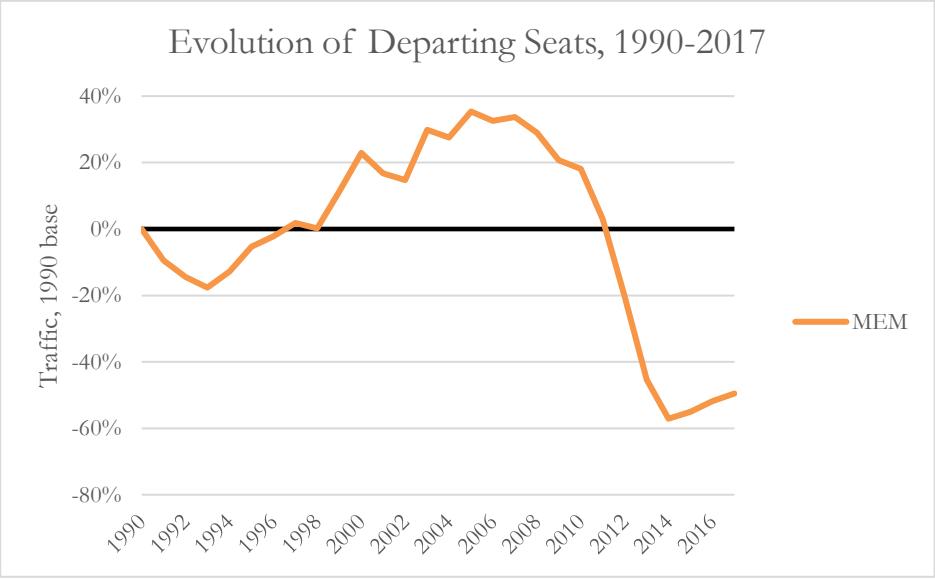

Figure 20 Evolution of departing seats at Memphis International Airport, 1990-2017 (OAG, 2018)

6.6 ACRP Report 76

The Airport Cooperative Research Program - ACRP is an effort sponsored by the Federal Aviation Administration (FAA) to conduct unbiased and reliable research aimed to solve common problems, learn about new technologies, and assess innovations in service and operations. Report 76 titled *Addressing Uncertainty about Future Airport Activity Levels in Airport Decision Making* provides a systems analysis methodology that augments standard airport master planning and strategic planning approaches. The methodology includes a set of tools for improving the understanding and application of risk and uncertainty in air traffic forecasts as well as for increasing the overall effectiveness of airport planning and decision making (Transportation Research Board, 2012).

The document starts by presenting how uncertain airport activity can be, as they are subject to a large array of uncertainties both market wide and project specific. When compared to the forecasted level during the master planning process, actual demand levels are found to be different due to unexpected events or changing conditions. The effect that deviations from the forecast may have can be dramatic in some cases. Six airports are used as examples of what can happen when the forecast is wrong.

The traditional forecasting practice addresses uncertainty in air traffic activity in various ways. Supplementing the base-case forecasts with high and low forecasts, including conditional scenarios (where extraordinary conditions materialize), or performing sensitivity analyses are common ways of doing so. However, experts' capacity of predicting and forecasting the impact of rare or high-impact events is fairly limited. These events are precisely the ones that lead to service disruption, financial distress, bankruptcies, and bailouts. Under the umbrella of *real options* various alternative strategies of flexible airport planning are identified. Among them, the following are especially relevant:

- Land banking
- Reservation of terminal space
- Trigger points/thresholds
- Modular or incremental development
- Common-use facilities/equipment
- Linear terminal design and centralized processing facilities
- Swing gates or spaces
- Non-load-bearing (or glass) walls
- Use of cheap, temporary buildings
- Self-propelled people movers (e.g., buses) rather than fixed transit systems
- Air service development
- Development of non-aeronautical revenues and ancillary activities

The document then proposes a systems analysis framework and methodology that are designed to assist airport decision makers with identifying and characterizing risks (threats or opportunities), including their plausibility and magnitude; assessing the impact of these threats and opportunities (i.e., determining what could happen, to which air facility, and when it might occur); and developing response strategies to avoid or lessen the impact of threats or foster the realization of opportunities. It is conceived as a complement to the traditional master planning process, allowing planners to consider a broad range of events and risks and help them anticipate possible changes that may occur. The methodology has 5 steps whose level of detail should be adjusted according to the scope of the project being analyzed:

1. Identify and quantify risk and uncertainty
2. Assess cumulative impacts
3. Identify risk response strategies
4. Evaluate risk response strategies
5. Risk tracking and evaluation

The methodology is based on identified risks or known unknowns. Unfortunately, uncertainty exceeds human imagination and reach which is why unidentified risks (unknown unknowns) also exist. These type of black swan events are the ones that fall in the *force majeure* category previously described: as those that exceed the normal risk alea. Despite their unpredictability, a planning process based on the proposed methodology will, on average, exhibit better results than the alternative.

Finally, the document states that the application of the system analysis methodology will help advance a series of goals (Transportation Research Board, 2012). First, it will increase the awareness of the degree of risk and uncertainty facing an airport through participative approaches with the airport management team and other relevant stakeholders. Second, it will increase the robustness by encouraging planning and design concepts that allow greater flexibility to deal with unexpected and unplanned events and circumstances. Finally, it will increase the readiness by having a reasonable road map to follow should certain events arise, deferring decisions until necessary or convenient.

6.7 El Dorado International Airport

El Dorado International Airport of the city of Bogotá is the gateway to Colombia and the northernmost hub of South America. It ranked first and second in the amount of cargo and passengers handled in the region in 2018, which is why it is considered a fundamental development factor for the Colombian economy.

Historically managed by Colombia's civil aviation authority Aerocivil, the government opened an international public tender in 2005 for a concession agreement or PPP. The decision of involving the private sector was motivated by the urgent need for expansion and modernization of the infrastructure and insufficient governmental budget to conduct it. In 2006, the OPAIN consortium was awarded a concession contract to manage the airport for 20 years and to invest in infrastructure, modernization and structural reinforcement. In exchange for it, the concessionaire would pay 46.16 percent of the gross income to Aerocivil (Aeronáutica Civil de Colombia, 2006).

The traffic forecast under which the government structured the concession contract was based on the 2001 Master Plan. However, by early 2009 it was clear that actual traffic far exceeded the expected demand. By then, the demand had exceeded the original projections by close to 40 percent (see Figure 21). As a consequence, OPAIN stated that the initial scope of the project was inadequate to guarantee the level of quality in the provision of the service recommended by IATA for the El Dorado airport and that there could be possible negative impacts to the provision of the service due to the unexpected change in demand.

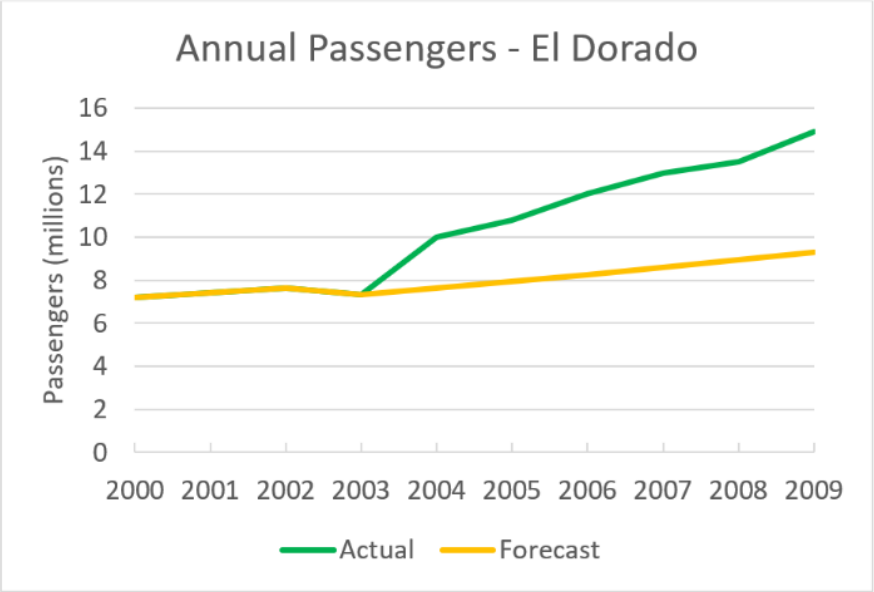

Figure 21 Actual vs Forecast Demand for El Dorado International Airport, (2000-2009) (T.Y. Lin International, 2009)

In December 2009, Contract Amendment No. 2 was signed agreeing to demolish the then current El Dorado terminals to make way for a new terminal suited for the current traffic conditions and expectations. The change in scope created an interesting challenge: calculating the amount of resources required to maintain the same risk scheme (in terms of impacts and occurrence probabilities) of the initial project in the new one. This figure was referred to as the Investment Delta. One of the fundamental aspects that introduced complexity to the valuation and negotiation

of the Delta is the fact that the State must guarantee that the exploitation and commercial operation of the new airport design did not alter the initial financial conditions under which the tender was carried out and the original concession contract was signed. This meant that the new design could not improve or diminish the financial conditions over which the concessionaire, to whom the concession was awarded, agreed to carry out the original works and to operate, manage, and maintain El Dorado. A Delta that resulted in a negative balance for the government would have to be paid through direct contributions from the State or by an extension of the initial contract up to 12 additional years. In 2012, Aerocivil agreed to amortize 402,000 million Colombian pesos over the next 15 years (Aeronáutica Civil de Colombia, 2009).

In 2016, the parties agreed to an expansion of the existing infrastructure due to the strong traffic growth that the airport had been experiencing (Agencia Nacional de Infraestructura, 2016). The 48,000 sqm addition was performed under the complementary and voluntary works contractual provisions, which allow interventions beyond the initial scope (and are part of all the contracts in the Colombian Fourth Generation of Concessions Program). Complementary works are requested and funded by the government, giving it the right over the entire revenue generated by them. On the other hand, voluntary works are requested and funded by the concessionaire following governmental approval. The revenue generated by them will be shared by the parties according to the formula defined in the concession contract. The following figure shows how the airport has been expanded recently under these contractual provisions (FII and FIII are complementary works).

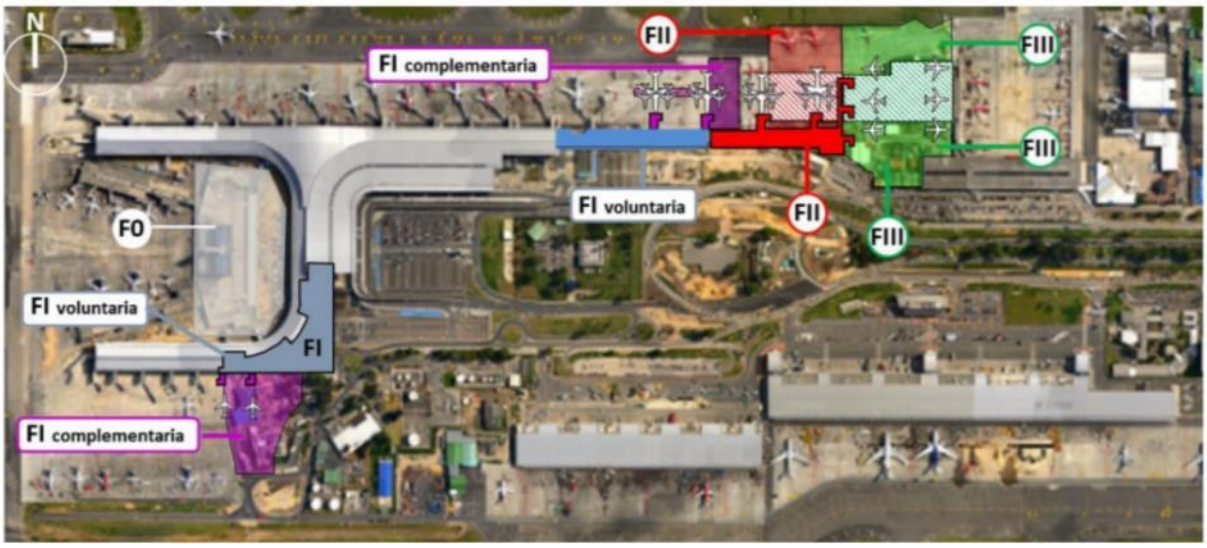

Figure 22 Complementary and Voluntary works at El Dorado International Airport (Agencia Nacional de Infraestructura, 2016)

6.7.1 Discussion

El Dorado's evolution is an argument in favor of flexibility in engineering design, where the upside of demand risk was and continues to be exploited. The airport has been expanded successively in the quest of catching up with its unforeseen success and further additions are being planned. However, the whole process could have been streamlined if the contract had included provisions that gave a higher degree of flexibility to the concessionaire. Important transaction and renegotiation costs could have been avoided, especially those surrounding the Investment Delta (up to date, the contract has been amended more than 29 times).

Voluntary and complementary works are an appropriate contractual mechanism for the sponsors of a project to react to new information and trends, allowing them to exploit upside opportunities as they arise.

6.8 Conclusion

Airport infrastructure can be de-risked technically through flexible, more cost-effective facilities that cater to the specific needs of the customers. In the case of airports, the involvement of airlines is desirable as it increases the cost effectiveness of capital expenditures and operations. A complete transfer of demand risk to airlines is not always possible despite being desirable, but the pragmatic effects can still be pursued through a collaborative planning and design process where non-technical motivations are reduced as much as possible. Developing markets, which are subject to higher market volatilities than developed countries do, can take foster and exploit synergies in airport development derived from partnering with airlines.

Chapter 7

CONCLUSIONS

This thesis proposes an engineering-based framework to mitigate demand and credit risks in PPPs, as a complement to traditional financial mechanisms. Infrastructure PPPs that are designed to face a vast range of future scenarios can better face the risks and uncertainties inherent to long-term contracts. Flexible engineering produces projects that can be less exposed to downside conditions and can better exploit the upside opportunities. This framework can be used to cost-effectively manage demand and credit risks and fully realize the potential of PPPs while scaling down the need for credit enhancements. Achieving a sustainable pipeline of less-risky, more-bankable projects should be well received by institutional investors seeking the long-term, stable and inflation-indexed returns of infrastructure projects. As a result, the consolidation of infrastructure as an asset class would be supported.

Every infrastructure public-private partnership ever designed has tried to address uncertainty with state-of-the-art mechanisms. This document presented some of them including cash sweeps, flexible repayment structure, bullet payments with refinancing, successive scopes, and scope ladders, among others. Most of them, however, fail to harness the power that the engineering design of an infrastructure project has to address uncertain conditions.

Flexibility in engineering design provides an effective tool to manage demand risk while mitigating the distortions and perverse incentives that credit enhancements may create in PPPs. Sovereign guarantees can potentially numb the incentives that are essential to address demand risk, while possibly generating opportunistic behavior. PPPs based on a flexible engineering design approach can strategically use the engineering design of the physical infrastructure to better accommodate uncertain futures. By achieving a higher and more transparent transfer of commercial risk to the private sector, the probability a project experiencing financial distress, bankruptcy, or governmental bailouts is reduced.

To achieve it, an integrated and recurrent design process involving negotiated collaborations between sponsors, technical experts, and financiers is necessary. Active engagement right from the start of a project has the potential of producing a technical-financial product that can better face future uncertainty. These efforts would be condensed in a strategic plan that provides the tools for

managers to adapt and adjust the systems as new information arises. The dialogue between key stakeholders must be sustained over the over the lifetime of the contract to achieve the consensus necessary to exercise the real options.

PPPs are a fertile ground for flexible infrastructure developments. As long as the quality of the service provided is within the Key Performance Indicators, the SPV has the competence to phase its investments as deemed adequate. Economies of scale will be sacrificed in this approach, but arguments in their favor are not overwhelmingly convincing in the light of massive uncertainty. By tailoring the engineering design to the expected needs in a shorter time frame – and embedding real options that enable subsequent phases – better outcomes are favored. If minimum investments are required by the government, minimum revenue guarantees should be provided too as the SPV was not free to optimize the design given the uncertainty.

The policy implications of flexible infrastructure developments are varied, given their strategic value for national governments. The natural monopoly nature of many infrastructure services requires a solid framework that address monopolistic behavior that can be detrimental to public interest. Flexible infrastructure contracts require regulatory frameworks that enable them while avoiding opportunistic behavior. As large infrastructure projects have multidimensional impacts, many governmental stakeholders (fiscal, environmental, public consultation, etc.) should be aware of the new approach and have the capacity to analyze, comment, and approve the evolution of strategic plans.

Given the strategically undefined scope proposed in this thesis for infrastructure projects, fiscal and disciplinary control agencies must be adapted to adequately follow the processes. Phased developments can be captured by vested interests and opportunistically used to advance actions against the public interest. This is exacerbated by the fact that once a contract is signed, the balance of power shifts in favor of the private party and the public sector loses negotiation capacity. To avoid this, it is essential to include clearly defined provisions in favor of the government to handle opportunistic behavior.

The government should have the capacity of bringing competitive bidding into subsequent phases with the purpose of guaranteeing market prices and best practices. The incumbent will naturally have a competitive advantage as it already has resources and capacity deployed in the field, as well as knowledge about specific field conditions. Under the suspicion of opportunistic behavior, contracts should include provisions for step-in rights by lenders or the government. A transparent process with clearly-defined rules must be defined that is fair to investors while providing adequate security to lenders.

It is clear that this document is far from solving the issues that uncertainty creates in project finance structures. There is no one right answer in terms of the strategies that can be used to face uncertainty in PPP Project Finance deals. Specific solutions will depend on precise legal, regulatory,

technical, and financial conditions. However, ignoring how engineering can shape the risk profile of a project and doing nothing about it misses very important opportunities. A de-risking approach based on flexibility in engineering can complement traditional contractual and financial approaches and allow a higher mobilization of capital to bridge an ever-increasing infrastructure gap.

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APPENDIX A

This Appendix compares the architectonical features of airport pairs in the United States and Europe with similar traffic compositions. Photographs of passenger terminal buildings (PTB) at Atlanta Hartsfield-Jackson (ATL), Los Angeles International (LAX), and San Francisco International (SFO) are contrasted to images of London Heathrow, Paris Charles de Gaulle, and Madrid Barajas Terminal 4. It is important to mention that the hypothesis of this document is based on the overall trend observed in airport PTB design. Exceptions will exist as airport development occurs in a social context with multiple dimensions to consider

The majority of US airport passenger terminals exhibit simple designs that can easily be replicable or modified. By themselves (i.e. excluding the jet bridges) they do not suggest that what is being observed is an airport terminal building that can handle millions of passengers per year. The simplicity of the design makes them easily replicable, as has been done in some airports.

In contrast, European airports do not represent simplicity. It is interesting how many exhibit signature roof lines, intricate structures, and one-of-a-kind designs. This uniqueness implies that traditional structural and constructive methods are not enough, resulting in more expensive structures. As they represent a concept more than just a structure, it is unlikely that one of them can easily be expanded or modified to accommodate different types of traffic.

Atlanta Hartsfield-Jackson International Airport

Figure 23 Atlanta Hartsfield-Jackson International Airport (taken from https://www.bizjournals.com/atlanta/news/2018/01/30/hartsfield-jackson-worlds-busiest-airport-for-20th.html)

Figure 24 Atlanta Hartsfield-Jackson International Airport (taken from https://www.waste360.com/composting/stalled-composting-recycling-project-atlanta-airport-regains-momentum)

Figure 25 Atlanta Hartsfield-Jackson International Airport (taken from http://www.cnn.com/2013/08/28/travel/airport-24-hours-storify/index.html)

Figure 26 Atlanta Hartsfield-Jackson International Airport (taken from https://www.thousandwonders.net/Hartsfield-Jackson+Atlanta+International+Airport)

London Heathrow International Airport

Figure 27 London Heathrow International Airport, Queen's Terminal (taken from https://www.skyscrapercity.com/showthread.php?t=403697)

Figure 28 London Heathrow International Airport Terminal 5 (taken from https://www.alamy.com/stock-photo/heathrow-airport-aerial.html)

Figure 29 London Heathrow International Airport Terminal 5 Satellite (taken from https://www.alamy.com/stock-photo/aerial-view-heathrow-airport.html)

Figure 30 London Heathrow International Airport (taken from https://www.ausbt.com.au/ba-to-consolidate-all-heathrow-flights-into-two-terminals)

Los Angeles International Airport

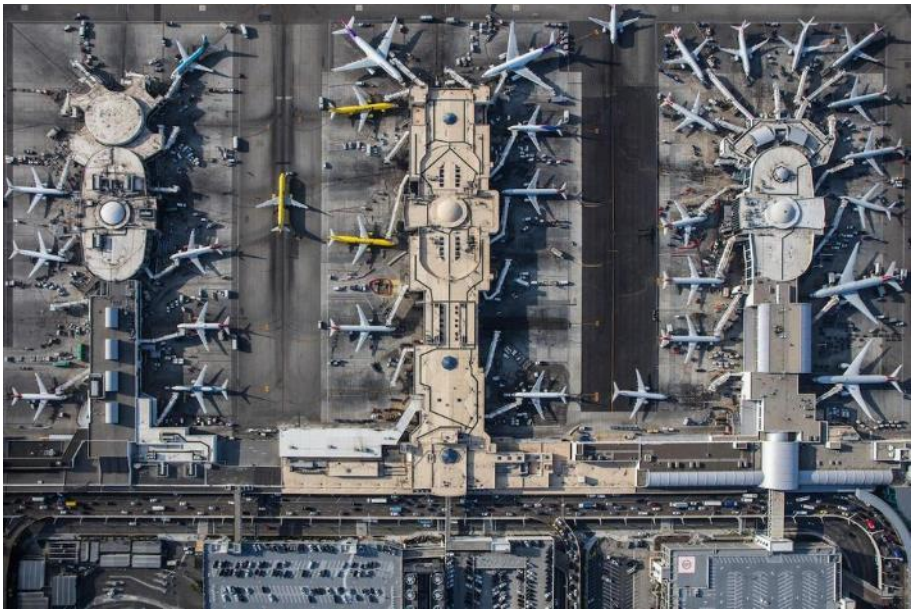

Figure 31 Los Angeles International Airport (taken from https://www.reddit.com/r/InfrastructurePorn/comments/7pvrcz/los_angeles_international_airport_lax_terminals_4/)

Figure 32 Los Angeles International Airport (taken from https://thepointsguy.com/2015/09/your-layover-guide-to-los-angeles/)

Figure 33 Los Angeles International Airport Tom Bradley International Terminal (taken from https://thepointsguy.com/2015/09/your-layover-guide-to-los-angeles/)

Figure 34 Los Angeles International Airport (taken from https://www.wings900.com/vb/model-airports/66609-lax-terminal-2-a.html)

Paris Charles de Gaulle International Airport

Figure 35 Paris Charles de Gaulle Airport (taken from [http://www.aircosmosinternational.com/green-light-for-paris-cdg-airport-express-train-link-88411)](http://www.aircosmosinternational.com/green-light-for-paris-cdg-airport-express-train-link-88411)

Charles-de-Gaulle)

Figure 36 Paris Charles de Gaulle Airport (taken from [http://loungeindex.com/Europe/France/CDG/index.htm)](http://loungeindex.com/Europe/France/CDG/index.htm)

Figure 37 Paris Charles de Gaulle Airport Terminal 1 (taken from http://www.sixtblog.co.uk/new-uk-car-hire-locations/car-hire-at-paris-charles-de-gaulle-airport/)

Figure 38 Paris Charles de Gaulle Airport (taken from https://www.traveldudes.org/travelblog/paris-cdg-airport-highlights-londons-airport-woes/15/12/17)

San Francisco International Airport

Figure 39 San Francisco International Airport (taken from https://sf.eater.com/2017/12/18/16790834/tartine-manufactory-cala-kin-khao-sfo-san-francisco-airport-food)

Figure 40 San Francisco International Airport (taken from https://www.flickr.com/photos/telstar/175253512)

Figure 41 San Francisco International Airport (taken from https://www.alamy.com/stock-photo/aerial-above-san-francisco-international-airport-sfo-aerialarchives-aeronautics.html)

Figure 42 San Francisco International Airport (taken from https://travelskills.com/2012/05/08/united-moving-flights-to-terminal-1-at-sfo/)

Madrid Barajas International Airport

Figure 43 Madrid Barajas International Airport – Terminal 4 (taken from https://www.designbuild-network.com/projects/madrid-barajas/)

Figure 44 Madrid Barajas International Airport – Terminal 4 (taken from https://www.ucm.es/english/barajas-airport)

Figure 45 Madrid Barajas International Airport – Terminal 4 (taken from https://www.alamy.com/stock-photo-terminal-4-madrid-barajas-airport-madrid-spain-61177261.html)

Figure 46 Madrid Barajas International Airport – Terminal 4 (taken from https://www.dragados.com/en/exp_tinnel_projet.php?type=Building)