Hedging Infrastructure Projects against COVID-19 type Disruptive Events with Term Extension Clause

Highlights

- Infrastructure concessions, especially for transportation projects, are risky long-term investments subject to demand volatility.
- Disruptive Events which are becoming more frequent, such as the Covid-19 Pandemic, significantly affect demand for traffic infrastructure, impacting the project cash flows.
- Analysis of demand series shows that these effects are usually transitory but may significantly impact the expected return of these ventures.
- We propose a real option-based approach to hedge the effects of such events by means of a concession term extension, proportional to the verified reduction in the demand and the duration of this reduction.
- We model traffic demand as a mean reversion with negative Poison jumps.

Abstract

Infrastructure concessions, especially for transport projects, are of long-term investments subject to demand volatility. Yet disruptive events, such as the Covid-19 pandemic, may negatively affect demand for traffic infrastructure, thus impacting the cash flows of such projects and decreasing the return of the concessionaire. Historical demand series shows that these events are more frequent than it would appear, but that their effects are usually transitory. In the analysis of passenger demand series in major airports in the United States, Europe, and Brazil, it is apparent how the Covid-19 pandemic affected demand for a period of time. Nonetheless, after the second year of the pandemic, demand resumed its historical levels with an observable time lag, but at a fast pace. We propose an approach to hedge the effects of such disruptive events by considering a concession term extension proportional to the observed reduction in the demand and the length of this reduction. We model this mechanism as a European Call Option on the time-term extension of the concession contract. Traffic demand is modeled as a mean reversion to which negative Poison jumps are added to simulate such disruptive events. Results are then compared to the case without real options.

Keywords: Infrastructure concessions; Covid-19; Disruptive events; Risk sharing mechanisms; Mean reversion with jumps.

1. Introduction / Contextualization

In the last decades, investments in infrastructure projects have transformed what was typically a government undertaking into a field that has attracted significant volumes of private sector capital. This trend has occurred worldwide and is one of the key drivers for the expansion of infrastructure ventures as governments tend to have limited financial resources for such types of outlays. On the other hand, private investors are attracted to the natural monopoly and long-term value characteristics of these ventures, which may be structured as concessions or Public-Private-Partnerships (P3). Under these arrangements, the objective of the government is to provide quality infrastructure services to the users, while the private partner earns a return on its invested capital. The condition is that the infrastructure is built and operated under the terms and rules put forward by the regulator or government. When well designed and implemented, such schemes bring about a win-win partnership for both government and the concessionaire.

Despite the attractiveness of the P3, its implementation is without trouble due to multiple uncertainties embedded with these long-term projects. Typically, the main source of uncertainty, especially in transportation infrastructure projects, is the future level of traffic demand, which may fluctuate for exogenous reasons such as seasonality and economic cycles, or endogenous, private factors as service quality, tariff value, etc. If this risk is deemed excessive, in some cases concession or P3 contracts may have risk-sharing clauses, namely provisions released by governments, such as Minimum Demand Guarantees (MDG) or others, to reduce the financial risk borne by the private investor to a level that makes the project feasible from the perspective of private risk capital and hence attractive for private investors.

Nonetheless, in recent years we have seen those disruptive events, such as the Covid-19 Pandemic, subprime market crash, oil crisis, and wars, tend to be more frequent than was previously assumed, and negatively affecting demand for traffic infrastructure, thus penalizing the cash flows of such projects and possibly turning a profitable venture into a loss. These disruptive events, although infrequent, have a strong economic impact worldwide, and in transportation projects in particular, placing unprecedented stresses on P3 projects, which are not covered by traditional risk mitigating clauses. In fact, observing passenger demand in the major airports in the United States, Europe, and Brazil, it is apparent how the Covid-19 pandemic affected demand for a period of time, and after the second year of the pandemic, demand resumed its historical levels with an observable time lag, but at a fast pace. Thus, it is reasonable to assume that this behavior also occurs in other types of transport demand.

The analysis of the historical time series of crude oil prices can help identify some of these events. Being a globally traded commodity, whose value affects almost all aspects of world´s economy as it affects production levels, inflation, interest rates, demand and others, it is clear that these events had significant impacts. In Figure 1 we can visually observe the impact of disruptive events, most of them exogenous to the oil industry, on the spot price of Brent in a 50 years' time span.

Several studies in the literature addressed the theme of demand for traffic infrastructure and its mitigation through public supports (Zapata Quimbayo, Mejía Vega & Marques, 2019; Carbonara, Costantino & Pellegrino, 2014a; Wibowo 2004) by proposing and analyzing several forms of public supports, such as Minimum Revenue Guarantee – MRG (Brandão & Saraiva 2008; Carbonara, Costantino & Pellegrino, 2014b; Carbonara & Pellegrino, 2018), Least Present Value of Revenue (LPVR) and concession period negotiation (Engel, Fischer & Galetovic, 2001; Xiong & Zhang, 2014), revenue sharing, and price cap (PC).

While existing studies recognize the importance of these instruments to mitigate demand risk for traffic infrastructure, they fail to analyze their applicability and efficacy in an unprecedented stress situation for P3 projects as those caused by disruptive events such as the Covid-19 pandemic. Such an analysis is important because the disruption and potential collapse of multiple P3 infrastructure projects will likely trigger simultaneously contractual provisions, thus posing significant challenges to governments.

Pursued by this gap, the present study proposes an approach to hedge the effects of such disruptive events by considering a concession term extension proportional to the observed reduction in the demand and the length of this reduction. We model this mechanism as a

European Call Option on the time-term extension of the concession contract. Traffic demand is modeled as a mean reversion to which negative Poison jumps are added to simulate such disruptive events. Results are then compared to the case without real options.

2. Literature Review

2.1. Impacts of disruptive events on P3 projects

Government interventions with public supports are traditionally considered a good way to share the risk of P3 and concession projects between public and private parties but some disruptive events are placing unprecedented stress on infrastructure projects. As the Covid-19 pandemic spreads and economies stagnate, the impact of abrupt reductions in economic activity continues to negatively impact the short-term viability of P3 and concessions. These types of projects have been put under a great deal of stress, compromising their economic and commercial sustainability, as a result of sharp drops in project income, particularly for public transit systems, toll highways, and airports. Due to the quick beginning and severity of the pandemic, it has become more and more likely that public agencies won't be able to fulfill all of their contractual responsibilities. Countries run the risk of their markets collapsing and recovery efforts being blocked by wrong decisions unless a rapid solution to support current P3 or concession projects and programs are developed (Casady & Baxter, 2020).

We emphasize that disruptive events like the Covid-19 pandemic are more frequent than they would seem, according to historical demand data, but they often have short-lived consequences. The analysis of the historical time series of crude oil prices can help identify some of these events. Being a globally traded commodity whose value affects almost all aspects of the world´s economy as it affects production levels, inflation, interest rates, demand, and others, it is clear that these events had significant impacts. In Figure 1 we can visually observe the impact of disruptive events, most of them exogenous to the oil industry, on the spot price of Brent in a 50 years time span.

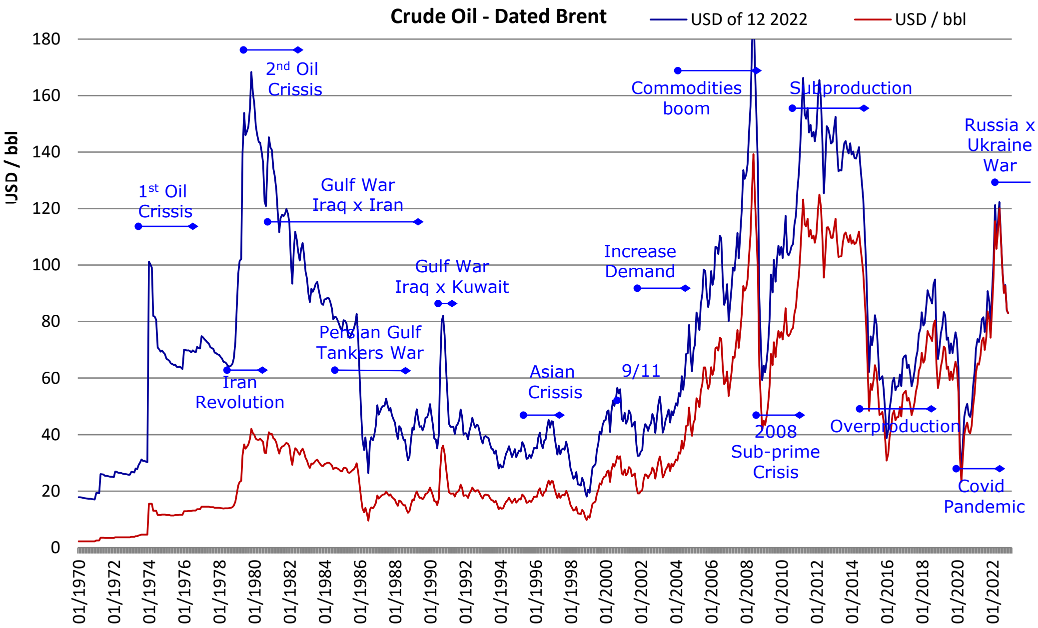

Figure 1 – Brent spot prices.

Note: Monthly average from Jan 1970 to Dec 2022, in historical nominal prices and in Dec 2022 USD.

If we consider the price of Brent as a proxy for disruptive events, it would appear that these are much more frequent than one could guess. By visual observation, we can count from 6 to 8 important up jumps in the time series as well as 6 to 8 important down jumps also.

Thus, in case of a disruptive event that generates a reduction in traffic demand below the guarantee level that is usually given by the government in P3 and concession projects, the contract requires a renegotiation of the terms. Generally, when demand is decreased to such a level, the project may not generate enough cash flow for the concessionaire to service its debt and will risk bankruptcy. If this situation lasts for more than a certain time, the concession investment will be seriously harmed and the concessionaire will probably abandon the ongoing project and sue for reparation. This is a situation unwanted by all parties involved. Yet such a condition is frequently the result of exogenous causes such as the disruptive events as we discussed previously, of which the Covid-19 pandemic is but one, although a significant one.

2.2. Mitigation instruments

The long-term uncertainties in P3 and concessions should not be ignored since they have the potential to dramatically affect the payoffs for project parties (Cruz & Marques, 2013). The revenue stream following the successful completion of construction is one of the key risk elements in this class of projects (Takashima, Yagi, & Takamori, 2010). The risk-sharing model proposed in this article assumes that the government will get the minimal amount if revenues are less than a value *k*, which implies that if net operational revenue is negative, the government will offer revenue subsidies. Under this mechanism, private capital may shoulder more of the costs associated with irreversible capital investments.

In this sense, the revenue-sharing arrangement grants the private firm a contingent, maximum credit that offers an unlimited premium during periods of strong income. The guarantee that the company can transfer ownership to the government if the revenue outlook drops below a specific level, and the company will be compensated in exchange for the transfer of rights, is another risk mitigation support analyzed in this study. Using the Real Options Approach (ROA), the authors show how much financial decision-making is impacted by the government guarantee and cost-sharing ratio.

Considering that future demand is also one of the most critical risk factors that affects the financial viability of a project, Buyukyoran and Gundes (2018) evaluate the Minimum Revenue Guarantee (MRG) by combining an optimization approach with Monte Carlo Simulation to identify the optimum upper and lower boundaries of guarantees. Analogously, Carbonara and Pellegrino (2018) develop a real options model to calculate the optimal revenue floor and ceiling values in a way that creates a win-win condition for the concessionaire and the government. The authors apply this model to the Strait of Messina Bridge case and conclude that this mechanism can support the decision-making process of the government in assessing the values of public subsidies necessary to make the project attractive to private investors.

Another mechanism used for mitigating demand risk is the Minimum Demand Guarantee (MDG), which is structured in two levels (Brandão & Saraiva, 2008; Galera & Soliño, 2010; Galera, Soliño & Abad, 2018; Rocha Armada, Pereira & Rodrigues, 2012; Song et al., 2018; and Wibowo, 2004). First, a lower band below the expected traffic demand, within which no compensation is owed to the concessionaire. Therefore, it is the range where the concessionaire assumes all the risk in demand. Below this range there is another band, or in some cases two, where the concessionaire receives compensation if the verified demand falls within this or these ranges. It is usual to couple these lower bands with a symmetrical set of upper bands, or ranges, in the upper side of demand around the expected traffic, where excess revenue will be returned to the government or regulator, therefore making the risk-sharing clause a neutral mechanism, also known as a collar clause (Marques et al., 2021, Brandão et al., 2012).

Furthermore, negotiation of the concession period is another way of proposing public support for mitigating demand risk. Researchers and practitioners are trying to figure out the essential elements that impact the duration of the concession period because it is known that the concession time is influenced by a number of unpredictable project variables (Ullah et al., 2016). For determining what duration of the concession period is appropriate, many models have been put forth. The core of several of these models is built using NPV (Net Present Value) analysis. The length of the concession term has been estimated to provide positive NPVs for both governments and private investors (Wu et al., 2012). Other researchers have developed, using NPV and Monte Carlo simulation analysis, a win-win model calculating the duration of the concession period (Carbonara et al., 2014a). By ensuring a minimum profit for both the government and the private sector, the proposed model determines the concession period capable of satisfying both groups while equitably sharing the associated risks.

As we can observe, many studies examine how to successfully ensure the computation of MRG, MDG or MTG. However, there is a lack of research that examines the relationship between the concession time and these risk sharing mechanisms, and no study effort simultaneously optimizes the concession period and the guarantee levels. Jin et al. (2021) closes this gap by offering a synthetic metric that uses a stepwise procedure to get the best values for the combined concession period and MRG. First, they identify the unknown and crucial factors for P3 and concession projects. Then, they propose a flawed information bargaining model in order to determine the rate of return on investment. To calculate the NPVs of operational income for private investors and governments, respectively, a simulation analysis is done in the third step. Finally, the simulation results are used to establish the concession period and MRG intervals. The best combinations of the concession duration and MRG will be identified based on the equilibrium rate of return, the decision intervals of the concession period, and the MRG.

This literature review reveals the patterns of various government guarantees and demonstrates how they can fail to protect the public and the private against disruptive and unpredictable events such as the Covid-19 pandemic. Therefore, we suggest a real options model to mitigate the consequences of such disruptive occurrences by taking into account an option to extend the concession period equal to the observed decline in demand and the duration of this decline.

3. Model

We consider modeling a policy that can be part of the original concession contracts and which accounts for the type of disruptive events discussed previously that can impact a concession in place.

When the level defined previously as a term renegotiation level is reached by verified demand, the concessionaire will call for a term extension at the end of the original concession term. Therefore, should such an unforeseen situation arise, that drives the concession revenue bellow a level that is usually considered as the renegotiation level, the concessionaire will increase its years of cash flows thus compensating for the losses incurred during the crisis year or years. It is worth mentioning that such solutions have already been implemented in Brazil in the energy sector.

After years of severe drought, hydro energy generators could not be dispatched due to low reservoir levels but were still required to deliver energy to fulfill their existing electricity sales contracts. This forced them to purchase energy at very high prices in the spot market, incurring in significant financial losses and in some cases, bankruptcy. Many sued the regulator for their losses, and eventually, a solution was negotiated that allowed the generators to extend their concession terms for a number of years.

In a first moment, this article will consider a theoretical 20 years concession with compensation bands as described above, followed by a level we call the term extension level, which when reached gives the concessionaire a number of years of term extension at the end of the original term. In order to model such a band, initially the demand uncertainty must be modeled as a stochastic diffusion process.

In this case, the type of diffusion process to be used will be a Mean Reversion Model (MRM) coupled with random negative value jumps. This mixed diffusion process associates softer variations described by the MRM component, along with negative random jumps which result from disruptive events and are modeled through a Poisson process. This model is best described by Equation (1).

$$dS = \eta\left[\ln \bar{S} - \ln S\right] Sdt + \sigma Sdz + dq \qquad (1)$$

where S is the stochastic variable; α is the log of the long-term equilibrium level; η is the mean reversion speed parameter; σ is the volatility if the process; dq is the Poisson process, which is assumed uncorrelated to the Wiener dz process and has the following properties:

$$dq \begin{cases} 0 \text{ with probability } 1-\lambda dt \\ \phi \text{ with probability } \lambda dt \end{cases}$$

where λ is the frequency of jump occurrence and ϕ is the distribution of jump size. Initially, these jumps are considered uncorrelated to the market, so they have a null risk premium.

In Figure 2, two single trajectories considering only the MRM and another with the jump effect are plotted.

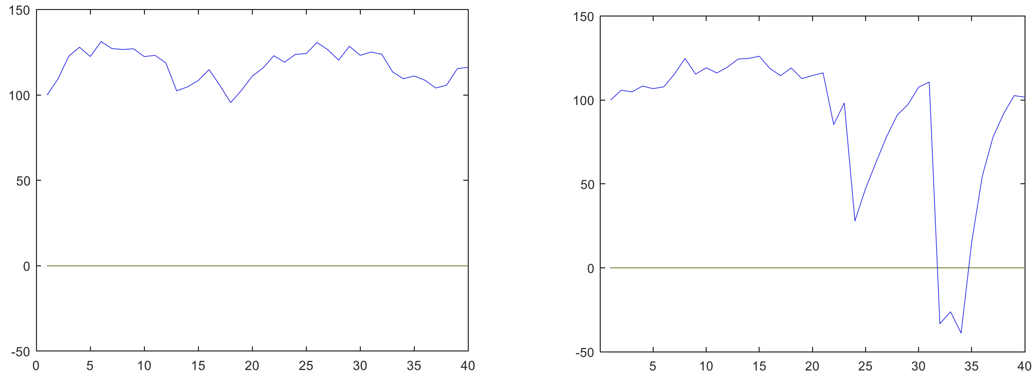

Figure 2 – Single trajectories considering MRM and jump effect.

Note: On the left side, we show a single trajectory of a Mean Reversion path simulation. On the right side, we show a simulation of the path of the same type of MRM but with an added negative Poisson jump, which happens two times in the 40-period simulation, and the return to normal levels under the effect of mean reversion.

For better understanding of the disruption effect, a set of 50 trajectories without and with jumps is shown in Figure 3:

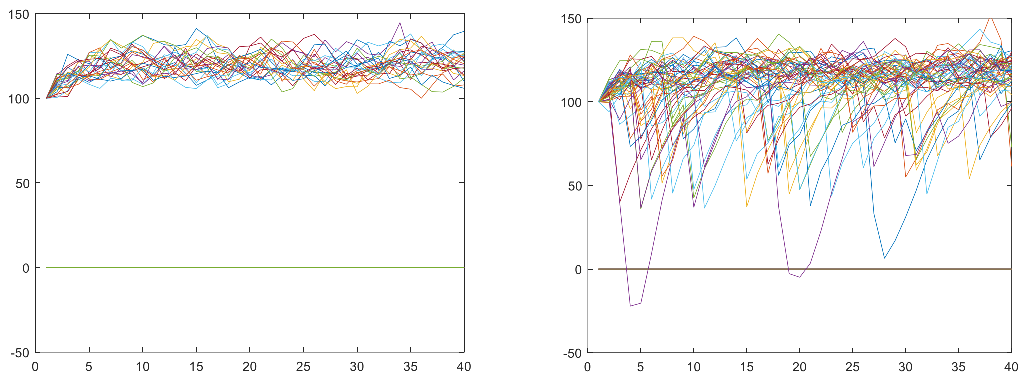

Figure 3 – Trajectories without and with jumps.

Note: On the left side, we show 50 trajectories of a Mean Reversion path simulation. On the right side, we show 50 simulations of path of the same type of MRM but with an added negative Poisson jump using a frequency of 5% or a 1/20th of the years of concession.

As the possibility of extending the original term is dependent on the demand behavior, which is uncertain, the Discounted Cash Flow (DCF) method is not adequate to value such a flexibility (term extension). Therefore, the appropriate method for valuing this type of projects is the Real Options Approach (ROA) and the exercise of the term extension is modeled as a European Call Option on the term length of the concession. When reaching a level defined previously, the concessionaire will add to is Value, the present value of a number of yearly Cash Flows which will take place at the end of the original term, or of this same term time, already augmented by eventual term increases from previous exercises of this call option from previous disrupting events.

4. Application

For a better illustration of the model proposed, use an example loosely based on a real case of the Salvador (BA – Brazil) Light Rail Vehicle concession as presented by Marques et al. (2020). The basic case of this concession considers 20 years' term, with an initial demand of 22.2 million passengers per year and an initial CapEx of 450 M.USD. We model demand as a Mean Reversion Model based on the Schwartz 1 model (Schwartz, 1997), considering the simulation equation (2).

$$S_t = \exp\left\{ \ln\left[S_{t-1}\right] e^{-\eta\Delta t} + \left[\ln\left(\bar{S}\right) - \frac{\sigma^2}{2\eta} \right]\left(1 - e^{-\eta\Delta t}\right) + \sigma\sqrt{\frac{1-e^{-2\eta\Delta t}}{2\eta}} N(0,1) \right\} \qquad (2)$$

Where, S_t is the demand variable, $\bar{S}$ the long-term equilibrium level, σ the volatility of the process, and η the mean reversion speed. All units are in yearly values as is the cash flow of the model.

We add to this model a negative discrete jump process, to simulate the possibility of disruption events and estimate their effect on the project's value. To model the jumps on the demand uncertain variable we use a discrete event distribution with yearly probability λ, which multiplies a *Pert* distribution ranging from 0, to -2, with maximum at -1, and with a size of 10 million passengers/year. The Pert distribution is convenient as it is bounded at its maximum and minimum values and has a rounded shape aspect, more adequate than a triangular one that could also be used but less realistic.

The parameters used in this initial model are listed in table 1.

Mean reversion volatility σ	8%	Per year
Mean reversion speed η	0.2	Per year
Initial value of Demand D_0	22.2	Million passengers / year
Long term expected Demand $\bar{S}$	26	Million passengers / year
Frequency of Disruption Events λ	10%	Per year
Size of Events (jumps)	-10	Million passengers / year

Table 1 – Parameters of Mean Reversion Model with Jump diffusion events

In order to test our assumption on using a Term Extension to compensate or hedge the effects of Disruption Events like Covid-19 on such an Infrastructure Concession Project, we also test a guarantee option with the following compensation: for every year of occurrence of a Jump Event, the concessionaire gets two years of term extension at the end of the original concession term of 20 years.

We ran 3 simulation models to verify our first assumptions on the Present Values ($) of the project with different assumptions as to its demand uncertainty:

- PV w MR Present Value with Mean Reversion on Demand
- PV w J Present Value with Mean Reversion and Jump events on Demand
- PV w J&Comp Present Value with Mean Reversion and Jump events on Demand and compensation with term extension for Jump occurrence

As these flexibilities are a bundle of European-type options, we model them using Monte Carlo Simulation. The first results are shown in Figure 4.

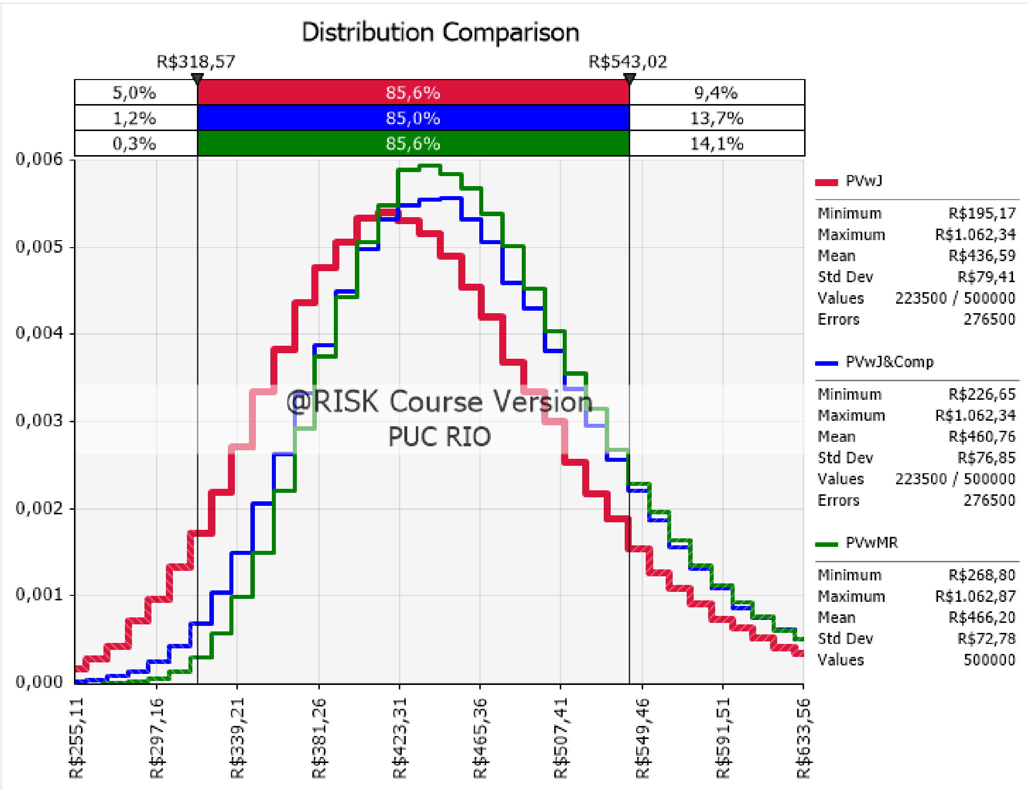

Figure 4. Distribution Comparison of Simulation for 3 models used: Present Value with Mean Reversion (MR), MR w Jumps (MRwJ) and MRwJ and Compensation (MRwJ&Comp).

By observation of Figure 4, it becomes apparent that the Jump events (red line) cause a shift to the left on the original with only MR distribution (green line), thus yielding a reduction in value. When introducing the term extension (blue line) the distribution closely approaches the original one, therefore confirming its compensation effect. The numerical results of the simulations are displayed in Table 2.

Model	Present Value (M USD)	Std Dev (M. USD)	NPV (M. USD)
PVwMR	466,20	72,78	16,20
PVwJ	436,59	79,41	-13,41
PVwJ&Comp	460,76	76,85	10,76

Table 2 – Simulation results for the models used

Development:

The article will develop the model to be used with the stochastic process described above. Then the Real Options model will be described to be used with Monte Carlo Simulation, as it will value European type options. In sequence several sensibilities will be analyzed, and applied to the stochastic process parameters, such as volatility, mean reversion speed, jump frequency, jump values and distribution (normal, pert, triangular,…), and also on the rules of exercise such as rules of exercise, number of years per event, etc.

In sequence, the article will apply the model developed to a real project to be chosen and determine the effects for both government and concessionaire that a policy based on the principles here studied could have had.

Finally, the article will discuss the results and conclude.

References

Brandão, L. E., Bastian-Pinto, C., Gomes, L. L., & Labes, M. (2012). Government supports in public–private partnership contracts: Metro Line 4 of the São Paulo subway system. *Journal of Infrastructure Systems*, *18*(3), 218-225.

Brandão, L. E. T., & Saraiva, E. (2008). The option value of government guarantees in infrastructure projects. *Construction management and economics*, *26*(11), 1171-1180.

Buyukyoran, F., & Gundes, S. (2018). Optimized real options-based approach for government guarantees in PPP toll road projects. *Construction management and economics*, *36*(4), 203-216.

Carbonara, N., Costantino, N., & Pellegrino, R. (2014a). Concession period for PPPs: A win–win model for a fair risk sharing. *International Journal of Project Management*, *32*(7), 1223-1232.

Carbonara, N., Costantino, N., & Pellegrino, R. (2014b). Revenue guarantee in public-private partnerships: a fair risk allocation model. *Construction management and economics*, *32*(4), 403-415.

Carbonara, N., & Pellegrino, R. (2018). Revenue guarantee in public–private partnerships: a win–win model. *Construction management and economics*, *36*(10), 584-598.

Casady, C. B., & Baxter, D. (2020). Pandemics, public-private partnerships (PPPs), and force majeure | COVID-19 expectations and implications. *Construction Management and Economics*, *38*(12), 1077-1085.

Cruz, C. O., & Marques, R. C. (2013). Flexible contracts to cope with uncertainty in public–private partnerships. *International Journal of Project Management*, *31*(3), 473-483.

Galera, A. L. L., & Soliño, A. S. (2010). A real options approach for the valuation of highway concessions. *Transportation Science*, *44*(3), 416-427.

Galera, A. L., Soliño, A. S., & Abad, B. G. (2018). Sharing Risks in Toll Motorway Concessions: Subsidies as Real Options on Traffic Volume. *Journal of Infrastructure Systems*, *24*(4), 06018001.

Engel, E. M., Fischer, R. D., & Galetovic, A. (2001). Least-present-value-of-revenue auctions and highway franchising. *Journal of Political Economy*, *109*(5), 993-1020.

Jin, H., Liu, S., Sun, J., & Liu, C. (2021). Determining concession periods and minimum revenue guarantees in public-private-partnership agreements. *European Journal of Operational Research*, *291*(2), 512-524.

Marques, N. L., Bastian-Pinto, C. L., Brandão, L. E. T., & Gonzaga, B. (2021). Evaluation of Flexible Concession Contracts. *In: The 24th Annual International Real Options Conference*, 2021, Porto. Annals.

Rocha Armada, M. J., Pereira, P. J., & Rodrigues, A. (2012). Optimal subsidies and guarantees in public–private partnerships. *The European Journal of Finance*, *18*(5), 469-495.

Schwartz, E. S. (1997). The stochastic behavior of commodity prices: Implications for valuation and hedging. *The Journal of finance*, *52*(3), 923-973.

Song, J., Yu, Y., Jin, L., & Feng, Z. (2018). Early termination compensation under demand uncertainty in public-private partnership projects. *International Journal of Strategic Property Management*, *22*(6), 532-543.

Takashima, R., Yagi, K., & Takamori, H. (2010). Government guarantees and risk sharing in public–private partnerships. *Review of Financial Economics*, *19*(2), 78-83.

Ullah, F., Ayub, B., Siddiqui, S. Q., & Thaheem, M. J. (2016). A review of public-private partnership: Critical factors of concession period. *Journal of Financial Management of Property and Construction*, *21*(3), 269-300.

Wibowo, A. (2004). Valuing guarantees in a BOT infrastructure project. *Engineering, construction and architectural management*.

Wu, M., Wing Chau, K., Shen, Q., & Yin Shen, L. (2012). Net Asset Value–Based Concession Duration Model for BOT Contracts. *Journal of Construction Engineering and Management*.

Xiong, W., & Zhang, X. (2016). The real option value of renegotiation in public–private partnerships. *Journal of Construction Engineering and Management*, *142*(8), 04016021.

Zapata Quimbayo, C. A., Mejía Vega, C. A., & Marques, N. L. (2019). Minimum revenue guarantees valuation in PPP projects under a mean reverting process. *Construction management and economics*, *37*(3), 121-138.