A REAL OPTIONS APPROACH TO EVALUATE FLEXIBLE-TERM CONCESSION CONTRACTS

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Abstract

LPVR type of auctions have been regarded as the best solution to demand risk sharing between concessionaire and regulators in infrastructure concessions. Yet implementation has been infrequent, mostly because of the strong opposition by concessionaires who do not see an equitable compensation for demand risk asymmetry. We review and analyze of all the aspects of LPVR auctions and other similar approaches of Flexible Term Concession (FTC), and propose a Real Options model that considers LPVR principles but treats uncertainties and flexibilities in a more informative and applicable way.

Keywords: concessions; real options; flexible-term contracts; infrastructure; auctions.

1 Introduction

The framework of Least Present Value of Revenue (LPVR) auctions (Engel, Fischer & Galetovic, 2001) proposes that instead of a reverse biding on tariff value or payment to the government, private firms should compete on the total present value of revenues the concessionaire will earn. The LPVR then states that as soon as this amount is reached, the concession term ends, and the assets return to the government.

The stated intent of this proposal is to deliver the best solution for both parties involved (regulator and concessionaire) in infrastructure and highways concession auctions. In order to verify this, we should first investigate what both parties aim to achieve. Although may appear to be straightforward, we will see that it is in fact not, especially when we consider the regulator perspective. Once these interests are clearly defined, it is a good practice to verify whether LPVR truly optimizes both sides' interests in finding an optimized model for franchising auctions, and therefore allowing for a win-win partnership.

The concessionaire´s objective in participating in government infrastructure auctions is straightforward: it seeks to get return on its invested capital, while considering issues such as time frame of investment, and especially financial risk. This last issue, risk, may have several facets such as regulatory environment, demand uncertainty, political stability, etc. These generally translate into a risk adjusted discount rate, used to take investment decision with internal rate of return (IRR) or net present value (NPV). Other aspects that can influence these objectives, are generally related to option like flexibilities, such as government guaranties, entry and exit options, or strategic investment issues.

On the other hand, we have the government or its mandated branch (we will refer to it as the regulator). Its objective or utility is much subtler: it should aim specifically at public welfare. Yet, frequently, it uses a financial grant from the concessionaire as the decision bid yielding the concession to the higher value offered. Other auction forms are reverse toll level competitions where it seeks to determine the concessionaire candidate that will accept the lower income level for its investment. Others still consider a pre-defined toll but with the concessionary competing for the shortest term of concession, or for the highest payment to the government. In all these cases, the concession is granted to the candidate that accepts to receive the lower value of return, contrary to their own interest. When lowering this expected return in order to compete for the grant, companies may even enter a negative payback. Sometimes concessionaires ask that governments pledge guaranties against demand or commercial risks in order to participate in the auction.

LPVR proposal points out that these auction forms don´t allocate risk correctly between both parties and frequently contracts are renegotiated when, for instance, demand is lower than expected, affecting return for the concessionaire. The authors argue that LPVR guarantees the return for the concessionaire and at the same time maximizes the regulator utility: as soon as the concessionaire return is attained through the PVR, the grant goes back to the regulator and Bob´s your uncle. Some of the LPVR assumptions are reviewed in Nombela & Russ (2004), but the basic principles remain the same and their model also is hampered in its practical implementation. Also, Vassalo (2010a) shows that LPVR scheme brings an asymmetry in risk profile since the upper positive tail of the return distribution is limited or caped while the lower tail is not. Therefore, the potential gains for the concessionaire are substantially limited while losses are not.

Thus, in this article, we discuss these assumptions and point out that several of the premises on which the LPVR is grounded are rather thorny to put together. We also propose a model that considers aspects of LPVR principles but treats uncertainties and flexibilities in a more practical and informative form that allows the model and exercise of real options, which do indeed bring an equilibrium model of risk allocation for both parties involved, fixing the asymmetry pointed out by Vassalo (2010a).

This paper is organized as follows: after this introduction we present a literature review covering applications and references of the model. In the following section, we comment and discuss on the principles and aspects of the LPVR model showing its advantages as well as implementation flaws. After this, we suggest a new approach that uses several aspects of the model but proposes diverse forms of modeling which can much more easily be put together and implemented. Finally, we discuss the approach and conclude.

2 Literature Review

Engel et al. (2001) are the first to show that fixed-term concession contracts do not allocate demand risk optimally. In this study, they propose the Least Present Value of Revenue (LPVR) auction, which optimally hedges the revenue uncertainty faced by the concessionaire by means of a flexible contract term. If demand is low, the term of the concession is extended, and if it is higher than expected the term is reduced. Nombela and de Rus (2004) extend the LPVR auction model and propose a new mechanism based on a flexible term contract and two-dimensional bids for total net revenue and maintenance costs, called Least Present Value of Net Revenue (LPVNR). Their results show that this mechanism allows to eliminate the risk of traffic and promote the selection of efficient concessionaires.

Vassalo (2010b) evaluates the effect that the LPVR discount rate, which is established by the government in the contract, has on the calculation of the traffic risk that is allocated to the concessionaire. Using a mathematical model, the author finds an inverse relation between these two variables and concludes that, although LPVR seems to be a very interesting approach, its practical implementation has been infrequent, mostly because of the strong opposition to LPVR by concessionaires. Rouhani, Geddes, Do, Gao, and Beheshtian (2018) review major revenue risk-sharing mechanisms developed worldwide. Regarding the LPVR approach, the authors state that this auction model allows to reduce the likelihood of renegotiations, but that it may not be as interesting when private operators are responsible for road quality or safety, since they are more willing to bear revenue risks in order to influence the level of road usage.

A research developed by Vassalo (2010a) shows that the main reason for the scarce implementation of flexible-term contracts lies in the strong opposition from the private sector to accept a mechanism whose risk profile is asymmetric, where the potential gains for the concessionaire are substantially limited while potential losses are not limited to almost the same degree. For example, among the 26 road projects that were granted in Chile until 2006, only four were tendered, and only two were successfully awarded under this approach (Vassalo, 2006). According to this author, the resistance to implement this mechanism occurs because, for the concessionaire, the LPVR does not improve the project's capacity to fulfill its commitments to the lenders; makes the concession operation difficult to organize; and limits the positive profitability of the concessionaire.

Albalate and Bel (2009) compare the benefits of allowing for flexible-term contracts rather than fixing a rigid term in concession projects by using real data from the oldest Spanish toll motorways. Their results show that if there is an unexpected increase in traffic, the concession period will be shorter, which will drastically reduce the benefits of the private agent. Xiong, Zhang, and Chen (2015) address the issue of compensation to the concessionaire in an early-terminated concession through a compensation estimation framework and a corresponding mathematical model. The results show that this model can improve the accuracy of measuring uncertainties present in an infrastructure project and provide a fair compensation system to safeguard the benefits of both private and public agents.

Carbonara, Costantino, and Pellegrino (2014) argue that the determination of the concession period needs to be managed in order to provide a beneficial condition for both parties involved in a concession. As a solution, they propose a model based on Monte Carlo simulation to determine the optimal concession period. Their results show that the concession period is able to guarantee a minimum profit and a fair risk allocation. Jin, Liu, Liu, and Udawatta (2019) also develop a model that uses Monte Carlo simulation to achieve this same objective. Their findings show that the optimal duration of a concession period should be long enough to control private investors' profit within a reasonable range while achieving a fair allocation of financial risk between governments and private investors.

In a work that specifically analyzes contract term extensions, Contreras and Angulo (2018) use real options approach (ROA) to determine the opportunity cost to the government of concession term extensions and conclude that these costs may be high in some cases. Besides contract term extensions, Xiong and Zhang (2014) also analyze two other compensation measures: toll adjustment and annual subsidy or unitary payment adjustment. The authors develop a quantitative compensation model to evaluate whether contract renegotiations are viable in concessions, considering that future traffic demand and operation and maintenance costs are stochastic variables. They conclude that the proposed model allows governments to compare different compensation measures and to select the most suitable for each concession project.

Jin, Liu, Sun, and Liu (2019) address the problem of optimizing the level of minimum revenue guarantees (MRG) and the length of the concession period to meet the interest of public and private parties in concession contracts. They propose an imperfect information trading model based on ROA and show that the length of the concession period is inversely proportional to the MRG level, and this correlation is influenced by the likelihood of reaching the equilibrium return rate of the investment. Lv, Ye, Liu, Shen, and Wang (2014) also develop a method that considers real options and game theory to determine the optimal concession period for BOT (build-operate-transfer) concession projects with government subsidies. Using a Chinese project as a numerical example, they find that this method allows to define the optimal concession period, especially when government subsidies are required to make the project financially viable.

Marques, Bastian-Pinto, and Brandão (2021) argue that flexible infrastructure contracts can overcome the difficulty of accurately forecast how market conditions and demand will evolve over the concession term. In this sense, they propose a model that combines capacity expansion decisions with conditional term extensions and model this flexibility under the ROA and the project value uncertainty as a Brownian Bridge. Their results show that these policies can be useful in attracting private investment in public infrastructure projects. Cruz and Marques (2013) also propose a real options model to evaluate the benefits of developing a flexible contract. They analyze the case of a hospital concession and verify that it is possible to find a contractual structure that maximizes the value for money when the uncertainties and flexibilities are taken into account in the project valuation.

3 LPVR model discussion

The authors of the LPVR proposal consider that, due to scarcity of resources, the government or regulator needs private investments for infrastructure construction, which are compensated by a tariff on the use of the concession once operational and for a defined time. They also assume that it has often been overlooked that medium and long-term traffic forecasts are very imprecise which leads to considerable demand uncertainty, most of it beyond the control of the concessionaire. Nevertheless, the model is built on a static level of demand throughout the term of the grant. They argue that the principles hold even if the demand is affected, and this premise is based on the principle of congestion tool. According to Engel et al. (2001):

> "The congestion toll is the toll that induces drivers to internalize congestion optimally in the absence of a self-financing constraint."

By this principle, the highway will always be used at its full capacity load, and this is achieved by setting the tariff at a level that will attract drivers to near congestion use. Being P^* the congestion toll and $Q(P)$ the corresponding demand, then the present value of revenues (PVR) can be defined by equation (1):

$$PVR = \int_0^T P^* Q(P) e^{-kt} dt \qquad (1)$$

where k is the cost of capital (WACC).

This also assumes that the auction for the concession is competitive, and the winner will have to accept the lower possible value of PVR and that this value is the amount expected to be invested in the concession, I. Therefore: $PVR - I = 0$.

The model considers that the highway will be built before demand Q reveals itself. But as the equilibrium above is to be kept ($PVR - I = 0$) then when bidding for the LPVR the candidate for the concession assumes the risk of over or underestimating the level of demand, and therefore the highway capacity to be built. That is, the value of I. The only contribution of the regulator at this level is that in the auction regulations, it sets the discount rate at which the revenues will be discounted as well as the levels of congestion tariff for different states of the demand.

Needless to say that the first flaw in this structure is that it ignores true cash flow structure of valuation, since Engel et al. (2001) assume that revenues are net for the concessionaire:

> "Large fraction of the costs of the franchise are sunk when the road is built and before demand becomes known; operating and maintenance costs are comparatively small and are therefore ignored."

Although this issue is partially corrected by Nombela & Rus (2004), these authors assume only fixed costs structure in their reviewed model called Least Present Value of Net Revenue (LPVNR), and propose that the above issue is corrected, transferring to the firms all the demand risk. They claim that:

> "One of the most remarkable characteristics of the LPVNR auction is that firms do not need to rely on any traffic estimate to compute their bids. This eliminates the bias towards the selection of optimistic candidates detected in the traditional auctions for road concessions."

Again, we find this unrealistic as on top of fixed costs, any infrastructure operation incurs in significant variable costs, income taxes, depreciation and maintenance investments which are necessary to the overcome depreciation as well as quality of the service rendered. We will show that only by considering fixed costs, the LPVR proposition of no risk for the concessionaire in the case of lower demand, and therefore longer term, is not true as this may yield a negative NPV while the biding proposition assumed at least a zero value NPV.

The principle of congestion tariff is also of difficult implementation as it implies in the following effect: if demand rises as an effect of greater welfare, the solution would be to rise toll, implying that the regulator proposes to squeeze augmented demand by increasing prices so as to keep congestion within the original road capacity. True welfare proposition would be, in this case, to expand road capacity while keeping tariff at and affordable level. On the other side of the demand spectrum, if demand reveals itself insufficient to cover the investment return, the concession will last forever. Again, this is not in the public interest and also not feasible for the private firm: in such a case, contrary to the LPVR calculation (remember it only considers Revenue) cash flows will probably be negative, or at least in present value, bellow the investment done. Therefore, no rational concessionaire will keep such a venture going on and will probably enter renegotiations.

4 A Real Options Approach to Flexible-Term Concession Contracts

In this section, we propose a model that considers some of the positive aspects of LPVR or LPVNR but adjusts to more realistic implementation aspects.

Although traffic demand Q is an important variable of any infrastructure investment, it is largely ignored ex-ante investment in the LPVR proposal. This is not only unrealistic but unpractical since projected road capacity is a direct result of Capital Investment and therefore will be the main driver of bid in any auction. In this sense, we plan to use a stochastic model which can simulate possible paths of future realization.

On a second level, the model will consider flexibilities as real options with which the concessionaire will react to demand, or market uncertainties, maximizing not only the concessionaire value but the regulator utility as well, as its main goal should be of providing infrastructure at the most adequate value or tariff. The main consequence of incorporating real options in a LPVR scheme of auctions is to correct the asymmetry of demand risk pointed out by Vassalo (2010a) that appears to be the main reason for the strong opposition from the private sector to accept such a scheme. Given this asymmetry, we will separate the model in two parts or areas: the downside or when things go wrong, and the upside, when things go better than expected.

In between these two scenarios or within a reasonable range of uncertainty, traffic risk sharing between regulator and concessionaire is well taken care off with the LPVR approach or one of the variants of it. The flexible term associated with the LPVR will adjust small variation of total traffic realization, assuming that two other variables of the model have been adequately quantified. These are the expected initial traffic demand Q_1, and its growth rate of drift rate, which affects the road capacity in terms of maximum traffic handling capacity and will determine the investment to be made by the concessionaire. Although this is usually a determination of the regulator, a wrong demand estimation will bear significant consequences affecting both sides. Inadequate CAPEX in road capacity will either result in an oversized road, implying in insufficient return since not enough traffic will generate revenues to cover its invested capital. Or, inversely, an undersized road generating more revenue than anticipated, but at a price of congestion, which is an undesirable feature from the regulator perspective.

Similarly, the other variable: the tariff which will be fixed for the duration of the term, and which is not the object of bidding in the concession auction, has to be adequate, and not as Engel et al. (2001) imply, a congestion tariff. This would cause congestion as the name suggests. And has to be one that captures the demand traffic at the start of the concession period Q_0 as well as for an adequate duration of this. Therefore, assuming these quantities have been correctly estimated, the LPVR type of auction is still subject to two diametrically opposite situations depending on how the traffic demand Q_t turns out to be during the concession period. We analyze these in the following sections.

In this situation, it is important to consider the fact that from the concessionaire perspective, although it might have placed a bid on the total revenue expected (LPVR), its return will come from the resulting cash flows F_t. Moreover, these must account for O&M costs, depreciation, taxes and other cash outlays involved in the highway operation as well as financial cost of debt raised for the CAPEX involved. So, if Q_t is significantly lower than expected, resulting cash flows can even be negative. But well before that point, these will probably not result in a positive NPV when eventually the LPVR is reached, and the road returned to the regulator. If such a case occurs, the concessionaire will most certainly enter into negotiations either pursuing some sort of compensation from the regulator, or even an early termination of the project and a compensation for its invested capital that did not reach an adequate payback. In such cases, there is a frequent propensity of regulators to comply with such requests as these situations might turn out to be at the very least an embarrassment for them (Engel et al., 2001; Nombela et al., 2004; Vassallo et al., 2010a). Let us recall that the main utility of such a regulator should be of providing adequate infrastructure for the public.

Moreover, even early termination is undesirable, as it would imply in operation by the regulator of a not cost effective enterprise, which was what the regulator was seeking to avoid from the moment it decided to grant the operation to concessionaires. The possible occurrence of such a situation is a risk that must be considered by the concessionaire and will increase its cost of capital or the value of the LPVR in the auction, and this affects all possible interested concurrent participants. As a result, average values of LPVR bids will be higher and this turns out to be an undesirable feature for the regulator as well.

We develop a model of early termination of concession based not on time frame, as the LPVR approach does not directly consider a time term, but on a compensation value to the concessionaire that considers the realized total traffic demand captured by the highway project as a stochastic uncertainty. The compensation will be a treated as an American put option on the Net LPVR remaining to reach the value offered at the equivalent Net LPVR bid, considering operation cash outlays and taxes, as Nombela et al. (2004) suggests.

Besides, Vassallo et al. (2010a) points out that the LPVR approach has the virtue of quantifying such a compensation, as it is already the result of the auction bid: fair compensation should be the LPVR still left to reach the auction bid. But such an approach will have an incentive for early termination, as when time passes, the compensation value will decrease as LPVR increases, even though it might be resulting in not remunerative cash flows. Therefore, we will incorporate a financial penalty for earlier termination compensation, in the contractual form suggested by Marques et al. (2021), in such a way that too early a termination will yield no compensation, and as time surpasses a given mark, compensation starts to build up until it reaches the "fair value" of left Net LPVR necessary to reach the bid value. This time mark for compensation start can even be stated at the auction rules disclaimer.

4.1 Basic LPVR model with demand uncertainty

Initially, we consider a road concession, as the one used by (Marques et al., 2021), where total revenues can be defined by equation (2):

$$R_t = D_t \times T \tag{2}$$

where R_t are the total revenues in year *t*; D_t is the traffic demand in year *t* already considering Equivalent Vehicle Multiplier; *T* represents the toll rate, which we assume constant for the duration of the concession.

From these definitions, we can determine the cash flows in each year with equation (3):

$$F_t = [R_t(1-\gamma_t) - \delta - \Gamma](1-\pi) + \delta \tag{3}$$

where γ_t represents the variable cost ratio related to R_t; π is the income tax; Γ represents the fixed costs and δ is the depreciation, which is an annual capital expenditure for the operational maintenance of the infrastructure. To simplify the cash flow equation, we can express the project cash flows as a function of the demand *D*, as shown in equation (4):

$$F_t = f(D_t) \tag{4}$$

We also consider that o concession has a maximum time term of *n* years, and that the concessionaire has won the auction bid with a LPVR of *L*. Therefore, when *t* reaches *n*, we can calculate the value of *L* with equation (5):

$$L = \int_{t=1}^{n} R_t e^{-kt} dt \tag{5}$$

where *k* is discount rate stipulated in the auction rules (we will initially consider that it is also the concessionaire WACC), the concession is returned to the regulator. In this case the value of the concession project is determined as shown in equation (6):

$$V_0 = \int_{t=1}^{n} f(D_t) e^{-kt} dt \tag{6}$$

Then, we assume that the demand follows a Geometric Brownian Motion (GBM), as shown in equation (7):

$$dD_t = \mu D_t dt + \sigma_D D_t dz_t \tag{7}$$

where dD_t is the incremental variation of demand in the time interval *dt*; μ represents the expected growth rate of demand; σ_D is the demand volatility; and $dz_t = \varepsilon\sqrt{dt}$ represents the standard increment of Wiener, where $\varepsilon \approx N(0,1)$.

Subsequently we put up an example based on Marques et al. (2021) with values as shown in Table 1.

Table 1. Concession parameter and data based on a typical 400 km toll road in Brazil

Maximum Contract term (*N*)	30 years
CAPEX	USD 400 million
Fixed cost (Γ)	USD 10 million per year
Variable cost (γ)	25% of revenues
Tax rate (π)	34%
Depreciation (δ)	USD 12 million
Tariff	USD 18 per vehicle
Risk-free rate (r_f)	3.0% per year
Risk-adjusted rate (*k*)	7.0% per year
Initial yearly vehicle demand (D_0)	3,650,000 vehicles
Demand expected growth rate or drift (μ)	2%
Yearly Maximum Road capacity ($D_{\max1}$)	7,300,000 vehicles

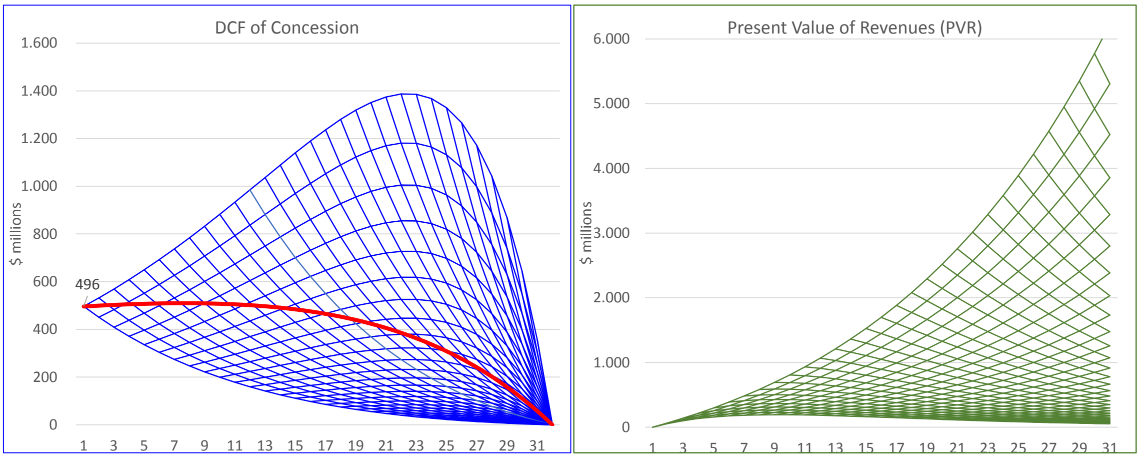
With these values, and without time frame limit or PVR limit, we get a project value of $ 496 million at t = 0, yielding a NPV of $ 96 million. Then, we consider a stochastic model to estimate demand *D* and, for this, we use the discrete binomial tree model of Cox, Ross, and Rubinstein (1979) (CRR). The model parameters for the CRR model are presented in equation (8):

$$u = e^{\sigma_D\sqrt{\Delta t}},\ \ d = \frac{1}{u}\ \ \ and\ \ \ p = \frac{\left(1+r_f\right)^{\Delta t} - d}{u-d} \tag{8}$$

where u and d are, respectively, the upside and downside multiplying factors; p is the risk-neutral probability; σ_D is the demand volatility; r_f is the risk-free rate; and Δt the discrete-time increment. We consider on the following examples a demand volatility of σ_D = 8% per year.

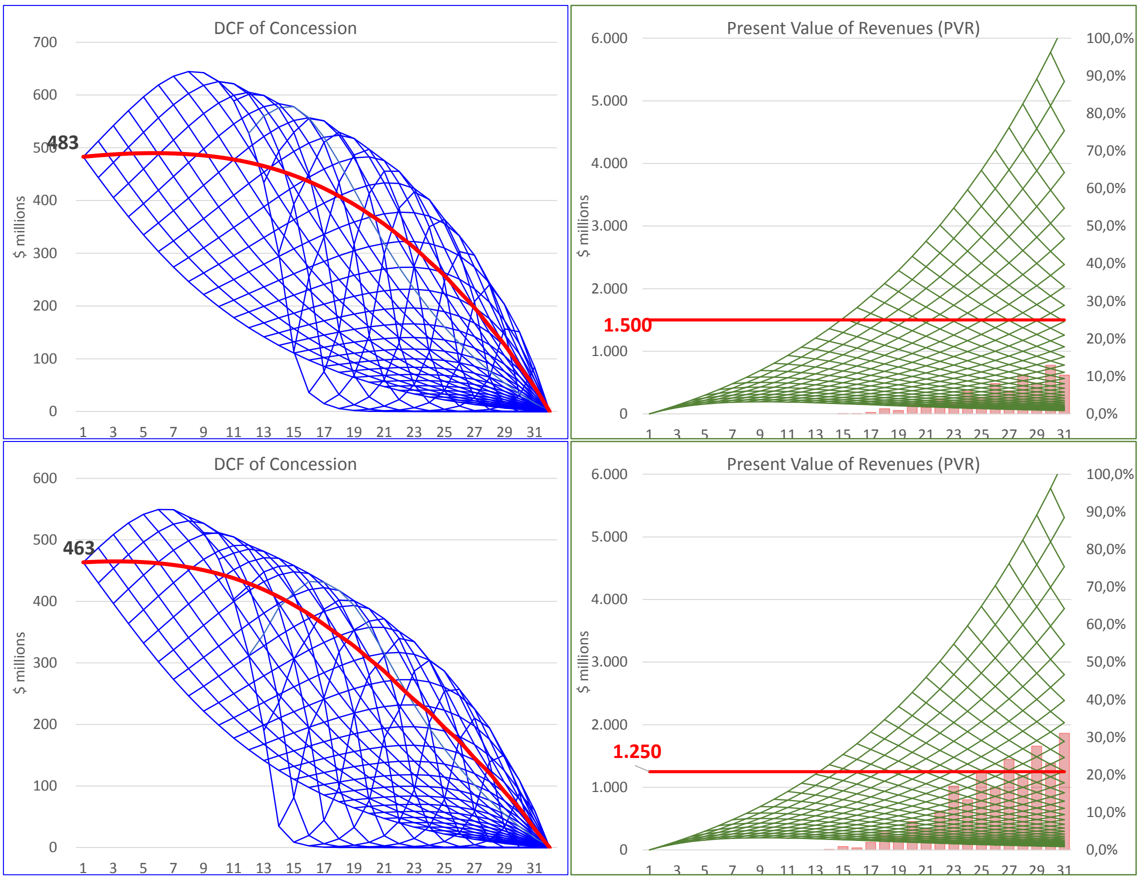
We initially model a demand lattice and then determine the equivalent cash flow lattice with equation (3). Discounting this lattice from *N*, we get a project value lattice and can also estimate the lattice of possible PVR. These are shown in Figure 1. Note that the lattice on the left (project value) is a discretization of a Brownian Bridge as Marques et al. (2021) describe. Also note that the lattice on the right side (PVR) in not limited in value since we did not yet input a LPVR (*L*) value.

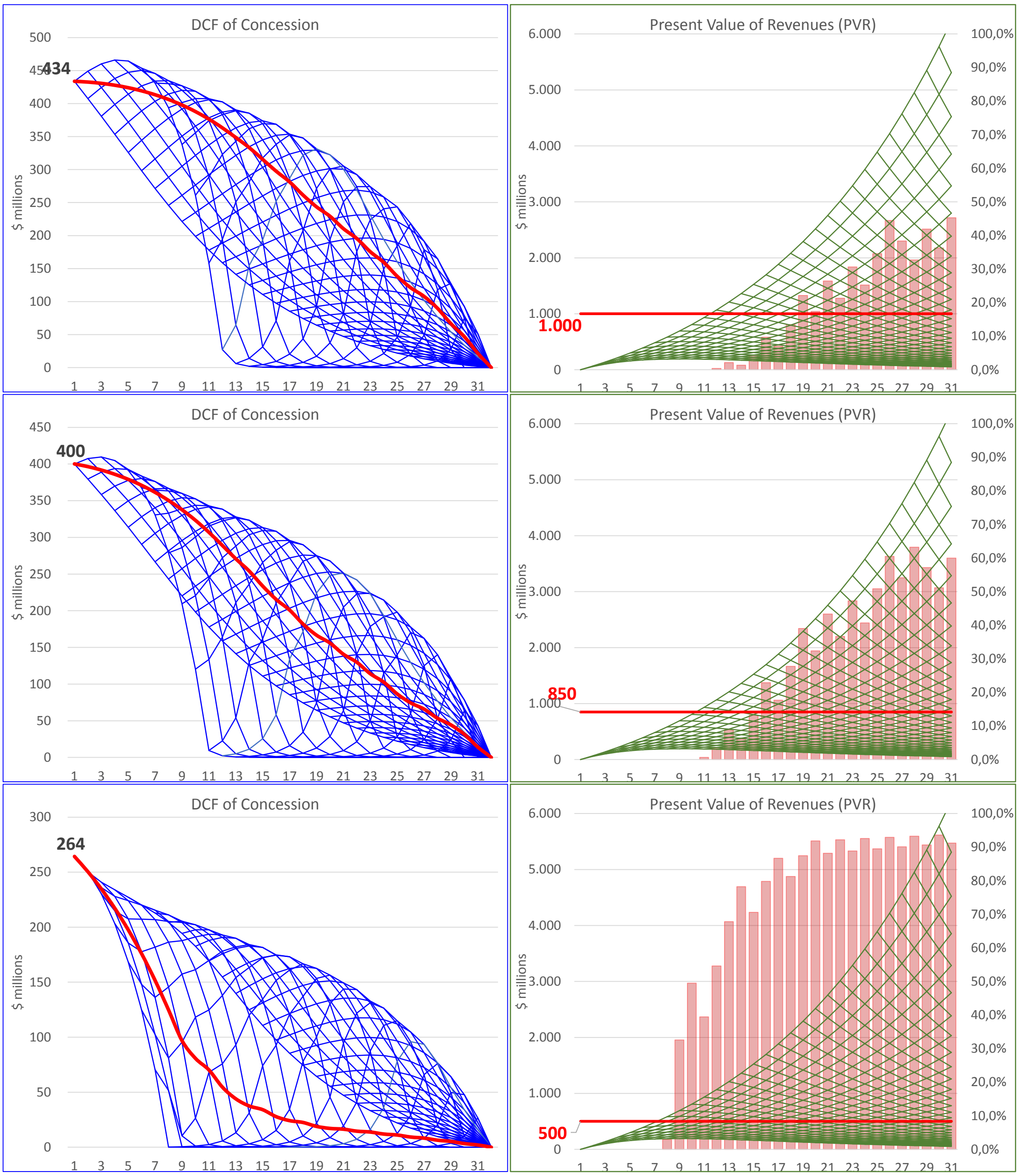
Figure 1. Project Value and PVR lattices ($ million)



With this stochastic model, we can input the LPVR limit to PVR, which we model as an American option in the project value lattice. We star with L = \$ 1.5 billion, then: L = \$ 1.25 billion, L = \$ 1.0 billion, L = \$ 0.85 billion and L = \$ 0.5 billion.

Figure 2. Project Value and PVR lattices with LPVR limit ($ million)





In the graphics of Figure 2 we can accompany the effect of LPVR (L) on the project value lattice and consequently on its NPV. As L drops, the project value lattice “folds” to zero, when L is attained reducing thus the value of the project to de concessionaire. We can observe that with these values of project, the zero value of NPV is obtained with approximately L = $ 0.85 billion, yielding a project value = $ 400 million, equal to the investment of the project.

Another important aspect that can be accompanied in these graphics is the probability of occurrence, as well as the timing, of the ending of the concession by LPVR attainment. The bar graphs on the right graphics with the right side scale show this probability at each time step of the lattice. The jagged aspect of the bars is due to the discrete nature of the lattice. Interesting to note that a zero value NPV is attained a little above *L* = $ 0.80 billion, and in this case, the probability of not attaining *L* is around 40% (complement of the last bar on graphic with *L* = $ 0.80 billion), which is significant and demonstrates the need for an early termination compensation option, should such a situation occur. On the other hand, high values of *L* show significant probabilities of never reaching the *L* value. These results are listed in Table 2.

Table 2. Concession parameter and data based on a typical 400 km toll road in Brazil

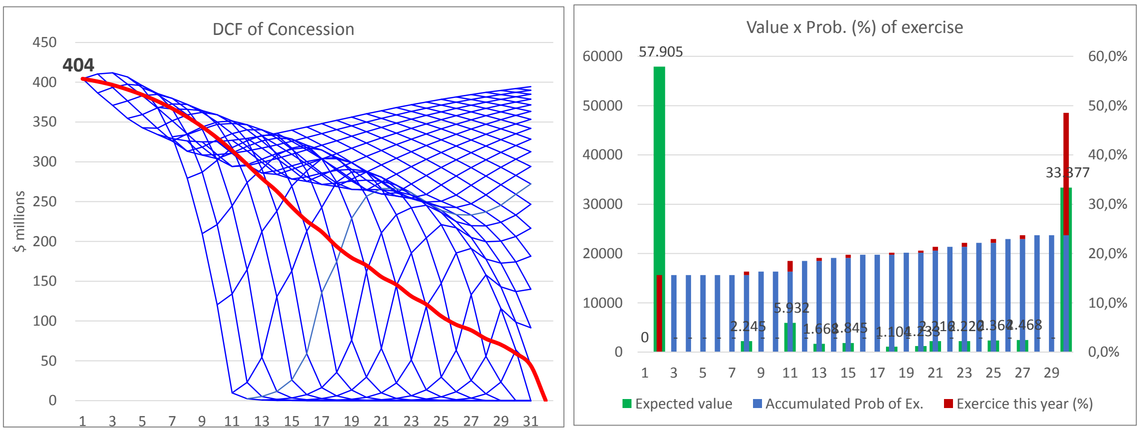
L ($ million)	Project Value ($ million)	% prob of not reaching *L*
No limit (base case)	496	NA
1.5	485	90%
1.25	463	75%
1.0	434	65%
0.84	400	45%
0.5	264	10%

While one would expect that the investment in expansion will occur when traffic demand reaches roadway capacity, this is not the case as the trigger for expansion is not the traffic level but the economic feasibility of this investment, which is driven by the project cash flows. Thus, both the demand and the cash flow lattices are needed to determine the optimal investment decision. The examples shown demonstrate that the possibility of higher than expected demand as well as lower than expected both need different contractual treatment to turn this type of auction model attractive to both government and concessionaire. We will therefore treat these real options in the following sections.

4.2 Traffic demand *D* significantly lower than expected

We initially use the model developed in 4.1 to implement a compensation to the concessionaire, equivalent to the project value corresponding to the difference PVR and *L* at every step of the value lattice modeled. We use the scenario for *L* = $ 0.85 billion as it is the one returning a zero NPV for the concessionaire and therefore all additional return from this early termination put option, is the value of the option itself. We can see the results in Figure 3.

Figure 3. Early termination option with full compensation

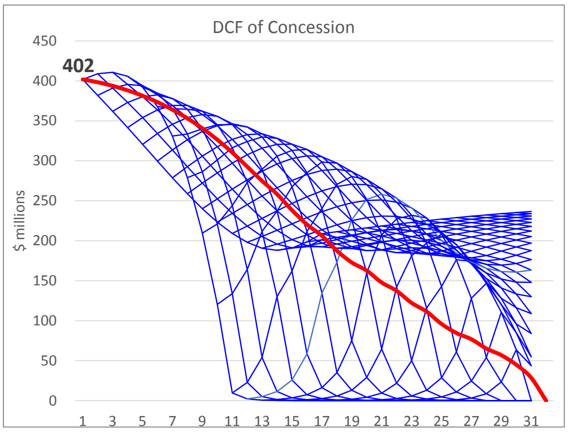


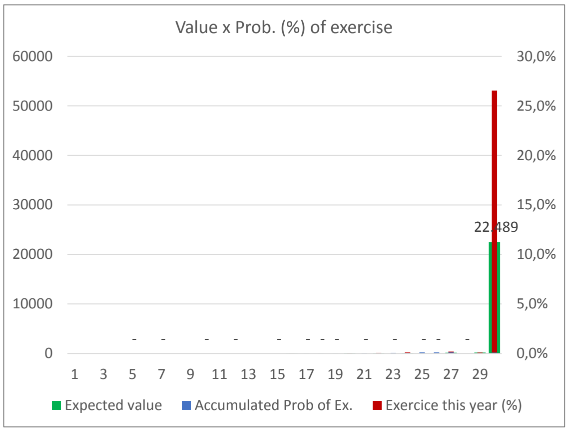
We can observe that the option of termination for compensation, will "fold" the lower part of the project value lattice to higher values signaling the compensation to the concessionaire and in the end of the term (30 years) it does not converge to zero as there will be compensation from the government. The option value is rather small ($ 4 million) as is common with put options, even with this exceedingly favorable scenario for the concessionaire.

In this scenario, without any penalty, it can be observed in the right side graphic of Figure 3 that almost all termination events will occur either in year 2 or at the term end (year 30). Especially in these years, the expected value of compensation to be paid is significant. As this is not realistic, the possibility of abandoning in any year, we tested several conditions for earlier limit in years of abandonment and penalty for compensation, in order to consider these limitations.

So, we limited the possibility of abandonment for only after year 15, which is half the time term of the concession. Also, a ceiling of 70% of the maximum compensation value described above. It is shown in Figure 4.

Figure 4. Early termination option only after year 15 with 70% compensation





Almost all termination events will occur at the end of the term of 30 years, and only a few before that. These do not even show on the graphs as thy are insignificant.

4.3 Traffic demand *Q* significantly higher than expected

This is the opposite case of the previous section and deals with the upside of demand uncertainty. Risk sharing is twofold: on one side, the standard deviation of return uncertainty is the main quantification of risk. Also, asymmetry of distribution on these returns, is a risk increment aspect that must be accounted for. And with the LPVR type of auctions, there is a significant asymmetry of the risk distribution, as in principle lower results are the burden of the concessionaire, higher returns are capped by the auction mechanism. We showed that the LPVR intend to compensate lower demand through a longer term, will not bear the intended risk reduction proposed. But in the higher demand scenario as greater revenues come through, this also limit the "good risk" aspect of the project, as they anticipate the termination of the concession as thinks are going well. Therefore, the asymmetry anticipated by Nombela et al. (2004) prevents compensation of the downside risk of lower demand.

Another important issue not considered in the LPVR models is the fact that the highway investment was programmed for an expected demand volume *Q* and, even with an expected increase in such demand anticipated, there is a traffic capacity limit above which congestion will take place and the concessionaire will not be able to collect accordingly higher revenues. This traffic capacity limit (cap) is usually treated as a demand stochastic absorbing barrier and limits the upside of revenue that can be obtained. Although this cap does not apparently affect the concessionaire total return as the LPVR mechanism will proportionally increase the concession term until the bid value is reached, it has two drawbacks: first it will cause congestion because of highway capacity limit, which is a negative aspect from the regulator perspective. Secondly, as demand increases, it calls for highway capacity expansion, in order to attend the traffic wishing to use and pay for highway use. Nevertheless, as is the case with a number of concession projects, the LPVR mechanism prevents the concessionaire of investing in capacity expansion, no matter how high this unexpected demand might be.

The solution to this asymmetry in risk is to incorporate a capacity expansion option, in the form suggested by Marques et al. (2021), where the concessionaire "buys" more concession term through investment in roadway capacity expansion. This can be adapted to an LPVR or Net LPVR framework, by again "buying" a second LPVR value coupled with a capacity expansion investment, which can be modeled as an American call option. And, although this option exercise is a flexibility available, and not mandatory, to the concessionaire as it is incorporated in the initial auction rules, the corresponding value is reflected in the bids offered by the candidates to the concession.

Therefore, when incorporating both these put and call options in the LPVR or Net LPVR framework, not only the original asymmetry of the LPVR framework can be corrected, but also the value of the concession is itself increased for the concessionaire candidates and for the regulator as well, as it sees the risk associated with congestion reduced. In the following sections, we will initially develop the real options model incorporating the proposals of the present section, and apply these to a real concession project detailing the results obtained.

WORK IN PROGRESS: MODELING OF EXPANSION OPTION

5 Discussion

TO BE DEVELOPPED

6 Conclusions

TO BE DEVELOPPED

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