

# Flexible-Term Contracts for Road Franchising

Gustavo Nombela

University of Las Palmas (Spain)

Ginés de Rus

University of Las Palmas (Spain)

Visiting scholar at the Institute of Transportation Studies and UCTC  
University of California, Berkeley

March 2003

## Abstract

Private participation in road projects is increasing around the world. The most popular franchising mechanism is a concession contract, which allows a private firm to charge tolls to road users during a pre-determined period in order to recover its investments. Concessionaires are usually selected through auctions at which candidates submit bids for tolls, payments to the government, or minimum term to hold the contract. This paper discusses, in the context of road franchising, how this mechanism does not generally yield optimal outcomes and it induces the frequent contract renegotiations observed in road projects. A new franchising mechanism is proposed, based on flexible-term contracts and auctions with bids for total net revenue and maintenance costs. This new mechanism improves outcomes compared to fixed-term concessions, by eliminating traffic risk and promoting the selection of efficient concessionaires.

**Keywords:** roads, highways, franchising, concessions, auctions

**JEL codes:** D44, L91

---

We thank Andrés Gómez-Lobo, M<sup>a</sup> Angeles de Frutos, Samer Madanat, Teodosio Pérez Amaral, Antonio Estache, and seminar participants at the Institute of Transportation Studies (U.C.Berkeley), Fundación Empresa Pública (Madrid) and the universities of Zaragoza, Madrid-Complutense, Valencia, UIMP and Las Palmas, for all their useful comments and suggestions. Any remaining errors are of our exclusive responsibility. Financial support from CICYT (Project SEC99-1236-C02-02) and Secretaría de Estado de Educación y Universidades is gratefully acknowledged.

## 1. Introduction

The provision of roads has been traditionally a responsibility of governments. However, during the last decades there is a trend towards a more active participation of private investors in road projects, especially high capacity roads. A popular form of road franchising is the ‘concession contract’. Under this contract, a private firm assumes the task of building a road, financing all costs linked to the project, while the government allows it to charge tolls to users a predetermined period of time in order to recover its investment. Concession contracts are not only used for road projects, but in many other sectors.<sup>1</sup>

The objective of a road project is to provide mobility for people and freight at the minimum feasible cost. Road franchising generally implies that infrastructure costs are paid by motorists (though in some cases governments may contribute with ‘shadow-tolls’ to concessionaires). Government provision of free, and shadow-tolls roads, means that costs are financed by taxpayers. What is the best option for the objective pursued? Efficiency based arguments in favour of free roads are generally based on the existence of transaction costs associated to users’ payment (e.g. time spent by vehicles at toll-booths). However, new technologies for automatic toll-charging are reducing those transaction costs, at least for high capacity roads. Making motorists pay for infrastructure costs allows expanding road capacity more rationally and, on the other hand, it achieves a better allocation of resources if efficient peak-prices are used (Mohring and Harwitz, 1962; Newbery, 1989).

Road concessions face two difficulties for a proper operation. First, cost information is limited for governments, and there are usually several alternative firms which can build and operate a road. Second, there is a high degree of uncertainty about traffic levels that will use a road in the future (specially for greenfield projects with long lives).

A traditional solution to overcome the first of these problems is to select concessionaires through auctions at which firms submit bids for tolls on users, payments to the government, or even minimum period to hold the contract. All these mechanisms are similar in nature: a government tries to extract private information about costs by choosing the candidate with the best offer. Once the concessionaire has been selected, it builds the project and operates the road during a fixed-term, collecting tolls during that pre-determined period. Traffic uncertainty thus translates into revenue uncertainty for the firm that wins a concession contract. As a matter of fact, this uncertainty is one of

---

<sup>1</sup> Data from World Bank about infrastructure projects initiated during the 1990s in developing countries report the existence of more than 700 concession contracts. By sector, 45% of these contracts are transport projects, 25% water, 20% electricity, and 10% telecommunications. By region, 60% are located in Latin America, 20% in Asia, and 20% in Eastern Europe.

the main reasons for the frequent contract renegotiation of concessions and the failure of many projects.<sup>2</sup>

This paper shows that the traditional mechanism used to select concessionaires does not yield optimal outcomes. Furthermore, there is evidence that the type of auction used to select a concessionaire might have an impact on the future performance of an infrastructure project (Beato, 1998; Guasch, 2000). Using World Bank data on infrastructure projects, Guasch (2000) reports that 65 percent of all concession contracts are renegotiated. One interesting finding is that the probability of renegotiation is higher when the concessionaire is selected through an auction with bids for tolls (92 per cent of contracts renegotiated), than when firms bid for payments to the government (29 per cent).

A new franchising mechanism is proposed in this work, which aims to solve the problems induced by the fixed-term nature of concession contracts. The idea is to adjust the length of the contract according to actual traffic levels, in the line suggested by Engel et al (1997, 2001). The existence of annual fixed maintenance costs in road projects (personnel costs, equipment, pavement renewal, and so forth) may generate difficulties for flexible-term concessions, because these costs accumulate over time when contract-lengths are extended in situations of low demand. The proposed mechanism solves this problem by using an auction in which firms submit bids with two-dimensional offers: total net revenue and annual maintenance costs. By using more information about firms than traditional procedures, this new mechanism allows a better selection of concessionaires and it eliminates traffic risk (i.e., revenue uncertainty) from road projects.

The structure of the paper is the following. Section 2 describes the main principles and relevant variables for a road concession project. Section 3 discusses the problems suffered by traditional fixed-term concession contracts. Section 4 analyzes the advantages of flexible term concessions, while section 5 describes in detail the new mechanism proposed. Conclusions are presented in section 6.

## **2. Toll road concessions**

Consider the case of a project for a new high capacity road. This project is going to be implemented and financed by a private firm through a concession contract with a fixed term of  $T$  years. The firm builds the infrastructure during some initial period, which will be considered as the year of reference ( $t=0$ ). From  $t=1$  until  $t=T$ , the concessionaire is allowed to charge users a toll  $P$  (for simplicity, we will assume that all vehicles are identical, all of them drive the full length of the

---

<sup>2</sup> One dramatic example is a road program implemented in Mexico during the 1990s (52 concessions to build 6,000 km of new highways). Actual levels of demand were on average 68 percent below expectations, which caused financial troubles for concessionaires. In 1997, the Mexican government was forced to recover 25 of these concessions, assuming debts for US\$ 7.7 billion. Besides, losses for private investors were estimated in US\$ 3 billion (Fishbein and Babbar, 1996; Gómez-Ibáñez, 1997).

road, and there are no congestion problems). Each year, the road receives a total volume of  $Q$  vehicles, which is assumed to be constant during the life of the concession.<sup>3</sup>

Total infrastructure costs (including opportunity costs) are equal to  $I$ , evaluated in monetary terms of year  $t=0$ . During each year of the concession, the firm incurs into some maintenance and operation costs  $M$ . These costs are of fixed nature, and thus invariable to the level of traffic  $Q$ .<sup>4</sup>

Assuming time is continuous, a necessary condition for the project to be implementable by a private firm without any subsidy from the government is the following:

$$I = \int_0^T [P Q(P) - M] e^{-rt} dt \quad (1)$$

where  $Q(P)$  is the demand for the use of the road,  $Q' < 0$ , and  $r$  is an interest rate of reference used for discounting all revenues and costs to their equivalent values at  $t=0$ .

Consider that the infrastructure has a life of  $\bar{T}$  years, with  $\bar{T} > T$ . After the concession ends, the government itself operates the road during the period  $t=T \dots \bar{T}$ , charging a toll  $P_0 < P$ . Therefore, some new users will enter the road (because price is lowered). These are motorists who were excluded from the road during the period  $t=1 \dots T$ , because their utility was lower than  $P$ .<sup>5</sup>

Assume initially that the government has perfect information on all variables related to the road concession, i.e.  $I$  and  $M$  are known, and there is no uncertainty about  $Q$ . In that case, an optimal concession contract can be designed simply by selecting the best values for the toll  $P$  and the contract term  $T$  to maximize social welfare, subject to the feasibility constraint (1). Defining social welfare as the sum of consumer and producer surpluses, the optimal concession contract is the solution  $(P^*, T^*)$  to the following optimization program:

$$\begin{aligned} \text{Max}_{P,T} \quad & \int_0^T \int_p^\infty Q(z) e^{-rt} dz dt + \int_T^{\bar{T}} \int_{P_0}^\infty Q(z) e^{-rt} dz dt + \int_0^T [PQ(P) - M] e^{-rt} dt + \int_T^{\bar{T}} [P_0Q(P_0) - M] e^{-rt} dt - I \\ \text{s.t.} \quad & \int_0^T [PQ(P) - M] e^{-rt} dt = I \end{aligned} \quad (2)$$

<sup>3</sup> The model can be easily generalized to consider that traffic levels are  $Q_t$ , i.e. demand could change over time, and also that tolls and maintenance costs are indexed to inflation, but for simplicity of exposition it is assumed that all relevant variables are constant.

<sup>4</sup> Maintenance and operation of roads generate two types of costs: some of them are fixed (e.g., equipment and personnel costs, lighting, signalling renewal, and so forth) while others depend on traffic. In the model proposed here, it is not necessary to introduce explicitly those costs which depend on  $Q$ , because  $P$  can be interpreted as revenue per vehicle, net of variable maintenance costs. As shown below, only fixed maintenance costs  $M$  are relevant for the analysis.

<sup>5</sup>  $P_0$  can vary according to government's objectives. It could be higher, equal or lower than maintenance cost  $M$ , but lower than the toll  $P$  charged during the life of the concession in any case. Free access to the road at the end of the concession, i.e.  $P_0=0$ , is a particular case in which the government fully covers for maintenance costs  $M$ . Results presented below are valid for any toll level  $P_0$ , and the only effect when changing  $P_0$  is the level of social welfare achieved in equilibrium.

The first-order conditions are:

$$P \frac{dQ}{dP} = -\lambda Q(1-\varepsilon) \quad (3)$$

$$PQ - P_0Q_0 - \int_{P_0}^P Q(z) dz = -I(PQ - M) \quad (4)$$

where  $e$  is the absolute value of demand elasticity,  $e = -Q'(P/Q)$ , and  $I$  is the Lagrange multiplier of the feasibility constraint. Combining (3) and (4), the following condition characterizes the optimal concession contract  $(P^*, T^*)$ :

$$\frac{P^*Q(P^*) - P_0Q(P_0) - \int_{P_0}^{P^*} Q(z) dz}{P^*Q(P^*) - M} = \frac{P^* \frac{dQ}{dP}}{Q(P^*)(1-\varepsilon)} \quad (5)$$

The LHS term of expression (5) is the ratio between the marginal social welfare and the marginal private revenue resulting from introducing a change in the contract length  $T^*$ . Meanwhile, the RHS of (5) is the equivalent ratio when  $P^*$  is modified. The solution that maximizes social welfare is achieved when these two ratios are equalized.

The optimal toll  $P^*$  and the optimal contract length  $T^*$  are inversely linked through the feasibility constraint. This can be observed by transforming (1) into the following explicit form:

$$T^* = \frac{\ln\left(\frac{P^*Q(P^*) - M}{P^*Q(P^*) - M - rI}\right)}{r} \quad (6)$$

Equation (6) shows two results related to the feasibility of the road project. First, in order to have a meaningful value for  $T^*$ , we must necessarily have  $P^*Q - M > 0$ . This implies that toll revenues must at least cover for fixed maintenance costs  $M$ , otherwise the project could never recover infrastructure costs  $I$ . Second, net annual revenues should be higher than the annual yield that could be earned with the amount invested in the project,  $P^*Q - M > rI$ . Another conclusion that can be extracted from (6) is  $dT^*/dr > 0$ , which indicates that the optimal term  $T^*$  is longer as the interest rate increases.

The following simplification of condition (5):

$$\frac{\int_{Q^*}^{Q_0} P(Q) dQ}{P^*Q(P^*) - M} = \frac{\varepsilon}{1-\varepsilon} \quad (7)$$

can be read together with equation (6) to provide an interesting conclusion about the optimal contract  $(P^*, T^*)$ . Expression (7) shows that the ratio between foregone benefits from excluded users (measured through the inverse demand function  $P(Q)$ ) and the concessionaire's annual net revenue  $PQ - M$ , depends on the elasticity of demand  $e$ . When demand for the road tends to be

inelastic ( $e \rightarrow 0$ ), the optimal concession contract has a high toll  $P^*$  and a short duration  $T^*$ . Meanwhile, if demand is relatively elastic ( $e \rightarrow 1$ ), the opposite type of contract, with a low toll and a long duration, is a better option. Condition (7) also indicates that the higher (in absolute value) is the elasticity of demand, the higher is the annual welfare loss incurred into when collecting the required revenue during the concession term.

It is important to notice that the optimal solution must necessarily be achieved at a point where the elasticity of demand is lower than one. This may be observed in equation (6). If the contract  $(P; T)$  were designed so that  $e > 1$ , it could then be possible to lower toll  $P$  and, at the same time, increase revenue  $PQ(P)$ . According to (6), an increase of revenue would imply a shorter length  $T^*$ . Since lowering  $P$  and shortening  $T$  would result in a higher level of social welfare, the optimal contract must necessarily be achieved for a situation with  $e < 1$ .

### 3. Fixed-term concession contracts

A government wishing to implement the optimal concession contract  $(P^*, T^*)$  faces two difficulties. First, there is asymmetric information on  $I$  and  $M$ . Although the government might have some cost estimates, actual values for those variables will only be known by the concessionaire. Second, there is uncertainty about the value of  $Q(P)$ , specially for new roads, and this may affect severely the financial equilibrium of a private firm with a concession contract.

The usual method to overcome the asymmetry of information on costs is an auction, which is an efficient mechanism to try to extract information from firms<sup>6</sup>. Usually, a government may receive offers from several firms to build a project. These firms will probably have different degrees of efficiency, and the objective of the government will be to select the candidate with the lowest costs.

Two types of sealed-envelope auctions are generally used to select concessionaires for infrastructure projects: (i) the government chooses a value for the contract length  $T$ , and invites firms to submit offers on the toll  $P$ , awarding the contract to the lowest bid; (ii) the government chooses  $T$  and  $P$ , and firms submit bids for a payment to be made to the government, with the highest bid obtaining the contract.<sup>7</sup>

We will show that, under uncertainty about future traffic levels, neither of these mechanisms yields optimal outcomes. In fact, the selection of the most efficient firm is not guaranteed, and, besides, financial problems might even arise for an efficient concessionaire during the life of the contract.

---

<sup>6</sup> For an introduction to auction theory, see Milgrom (1989) and Klemperer (1999).

<sup>7</sup> This latter type of auction can also work with bids for negative payments, i.e. subsidies to be received from the government, with the lowest bid winning the contract. Another feasible mechanism is an auction with bids for the lowest duration of the contract, which has been tried in practice for road projects. This mechanism is not discussed here, because it shares the fixed-term nature of the two alternatives presented, and it exhibits the same limitations.

For simplicity, consider that there exist  $n$  firms which can build and operate the road project. All firms are identical with respect to maintenance and operation costs  $M$ , but they differ on their efficiency levels regarding construction costs  $I_i$  (including the desired profitability over investments), so that  $I_1 < I_2 < \dots < I_n$ . In a perfect information scenario, firm 1 should be selected as concessionaire.

Construction costs  $I_i$  are private information for each firm. We assume that the only knowledge that a firm has about its rivals is a range of feasible values for construction costs,  $[I_{\min}, I_{\max}]$ , and probabilities follow a uniform distribution over that range (thus representing a situation of minimum information).

In order to compare both types of auctions -based on bids for tolls or payments- in a similar scenario of traffic, we assume that each firm  $i$  computes its bid based on some expected level of demand  $Q^e$ . This traffic expectation can be shared by all firms but, more generally, we will deal below with a situation in which traffic expectations may vary across firms.<sup>8</sup>

*(i) Auction based on bids for tolls*

At this type of auction, each candidate firm knows that it faces a trade-off when picking its bid  $P_i$ . As the contract length is fixed, a higher toll means more revenue for the concessionaire, but at the same time it lowers the probability of winning the contract. The optimal strategy results then from maximizing its expected profit, which can be defined as<sup>9</sup>:

$$P_i^e(P_i) = ([P_i Q^e - M] T - I_i) \text{ prob}(P_i) \quad (8)$$

where  $Q^e$  is the expected level of demand, and  $\text{prob}(P_i)$  is the probability of winning the auction with a bid  $P_i$ .

Assuming that all firms calculate their bids according to some function  $P(I_i)$ , and using the uniform distribution of construction costs of rivals, it is possible for any firm  $i$  to compute the probability of winning with a bid  $P_i$ . Confronted with another firm  $j$ , firm  $i$  wins if  $P_i < P_j$ , or, applying the inverse function  $P^{-1}(\cdot)$ , if  $P^{-1}(P_i) < P^{-1}(P_j) = I_j$ . Therefore, firm  $i$  knows that the probability of winning the contract with a bid  $P_i$  if there is only another candidate is equal to the probability of the event  $[I_j > P^{-1}(P_i)]$ .

---

<sup>8</sup> In the auction based on bids for tolls, instead of consider a fixed level of demand  $Q^e$ , the optimal bid  $P_i$  can be alternatively computed by considering that expected traffic depends on the offered toll, i.e.  $Q^e(P_i)$ . Results of both specifications are almost identical; the only change is that firms take into account the elasticity of demand when setting  $P_i$  in the latter case.

<sup>9</sup> For simplicity in the calculation of firms' bids at the auctions, no time discounting has been introduced in the definition of expected profits. For the same reason, equal maintenance costs for all firms,  $M_i=M, i=1\dots n$ , are assumed. Both these assumptions are relaxed below when discussing how to implement in practice the proposed new mechanism for flexible term concessions.

As there are  $n-1$  rivals at the auction, the probability of firm  $i$  winning the contract is:

$$prob_i = \left( prob [I_j > P^{-1}(P_i)] \right)^{n-1} = (I_{max} - I_{min})^{1-n} (I_{max} - P^{-1}(P_i))^{n-1} \quad (9)$$

The optimal bid  $P_i$  can be obtained by solving the maximization program:

$$Max_{P_i} P_i^e = \left( [P_i Q^e - M] T - I_i \right) (I_{max} - P^{-1}(P_i))^{n-1} I_r^{1-n} \quad (10)$$

where  $I_r = I_{max} - I_{min}$  is a constant that can be ignored. The first order condition of program (10) is a differential equation in terms of the bidding function  $P(\cdot)$ .<sup>10</sup>

Solving that equation, it is obtained that the optimal strategy is a linear function of  $I_i$ :

$$P(I_i) = \frac{I_i}{Q^e T} + \frac{M}{Q^e} + \frac{I_{max} - I_i}{n Q^e T} \quad (11)$$

Optimal bids  $P_1 \dots P_n$  resulting from expression (11) exhibit some interesting properties. First, when all firms have the same expected demand  $Q^e$ , the mechanism correctly selects firm 1, because the candidate with the lowest cost  $I_i$  wins the contract (observe that  $P_1 < P_2 < \dots < P_n$ ). Second, the toll submitted allows the concessionaire to obtain some positive profits, equal to  $(I_{max} - I_1)/n$ . This is the ‘information rent’ that firm 1 extracts from the government/users due to its advantage of private information. This rent decreases with the number of firms participating at the auction, and it tends to zero when  $n \rightarrow \infty$ .

What happens if uncertainty about future demand is high? In that case, it is likely that the assumption about all firms sharing the same belief on expected traffic  $Q^e$  must be abandoned. When firms participating at the auction have different beliefs  $Q_j^e$ , this mechanism does not longer guarantee that the most efficient candidate (firm 1) is selected. As a matter of fact, any firm  $j$  that is sufficiently optimistic about future traffic level might submit an offer  $P_j < P_1$  and win the contract instead of firm 1.

Expressing the expected demand by firm  $j$  in terms of firm 1’s expectation  $Q_1^e$  as:

$$Q_j^e = I_j Q_1^e \quad ; \quad with I_j > 1 \quad (12)$$

and considering that  $n$  is sufficiently large, so that information rents are negligible, the condition for firm  $j$  to win the concession contract over firm 1 is:

$$I_j > \frac{I_j + MT}{I_1 + MT} \quad (13)$$

---

<sup>10</sup> More details about how the function  $P(\cdot)$  is solved for are presented in Nombela and De Rus (2001).

Therefore, if the degree of ‘optimism’ about demand, measured by parameter  $I_j$ , is larger than the efficiency gap between firms  $j$  and 1, the inefficient firm  $j$  wins the contract. The auction winner will then be a firm with a relatively high expected traffic. This wrong selection has implications for the future: if traffic turns to be low, the concessionaire might easily enter into financial difficulties. The probability of bankruptcy, or at least the need to renegotiate the contract, is much higher than it could have been if the most efficient candidate were selected (because the concessionaire has high costs, and it made an offer for a low toll). The government, i.e. the taxpayer, is assuming this risk induced by the mechanism used for the concessionaire’s selection

(ii) *Auction based on bids for payments*

A second popular mechanism to select concessionaires for road projects is an auction at which the government pre-determines the values of  $T$  and  $P$  (chosen according to some cost estimates which it might have). Firms are then invited to submit offers for a payment to be made to the government, awarding then the contract to the firm that offers the highest payment. These payments may take the form of annual instalments or, equivalently for modelling purposes, a lump-sum payment  $Z$  due at the start of the concession.

The objective pursued by this mechanism is exactly the same as in the previous type of auction, that is, to extract information about the relative efficiency of candidates in order to select the best one. The logic is that a firm with low costs will be able to offer a high payment, thus allowing the government to rank firms according to their bids as a proxy for their efficiency ranking. If  $I_1 < I_2 < \dots < I_n$ , it is then expected that  $Z_1 > Z_2 > \dots > Z_n$ .

Each firm will calculate its bid  $Z_i$  as a function of its type  $I_i$ . As in the previous case, we again search for a symmetric equilibrium in which all candidates use the same function  $Z(\cdot)$ , with  $Z'(\cdot) < 0$ , to compute their bids  $Z_i$ . The probability of firm  $i$  winning the auction is now the probability of the event  $Z_i > Z_j$ , for any  $j$  other than  $i$ . In terms of construction costs, this can be expressed as:

$$prob_i = \left( prob[Z_i > Z_j] \right)^{n-1} = \left( prob[Z^{-1}(Z_i) < I_j] \right)^{n-1} = \left( I_{max} - Z^{-1}(Z_i) \right)^{n-1} I_r^{1-n} \quad (14)$$

Optimal strategies are then derived from the maximisation of expected profits:

$$Max_{Z_i} P_i^e = \left( [PQ^e - M]T - I_i - Z_i \right) \left( I_{max} - Z^{-1}(Z_i) \right)^{n-1} I_r^{1-n} \quad (15)$$

The first order condition of problem (15) is a differential equation that yields the solution:

$$Z_i(I_i) = (PQ^e - M)T - I_i - \frac{I_{max} - I_i}{n} \quad (16)$$

Optimal strategies on payments  $Z_i$  share the same properties of  $P_i$ . First, if firms had the same beliefs about future demand  $Q^e$ , the mechanism would select the most efficient firm in terms of construction costs. Second, the winner is able to extract some rent, because the proposed payment

to the government yields a positive expected profit equal to  $(I_{\max}-I_i)/n$ . This rent is equal to the one obtained by a winner of an auction based on bids for tolls. This is a “revenue-equivalence” type of result from the point of view of the winner, although the impact of each of type of auction is different for motorists and the government.<sup>11</sup>

When an auction based on tolls is used, road users pay for the rent  $(I_{\max}-I_i)/n$  that the concessionaire obtains, in the form of tolls which are higher than feasible according to costs. Meanwhile, when using an auction based on offers for payment, the rent is financed by taxpayers. In both cases, it is worth noticing the importance of having as many firms as possible competing for a concession contract. The number  $n$  of bidders reduces the information rent that a concessionaire may extract. In the limit, if  $n$  is sufficiently large, the rent goes to zero and the government attains the minimum cost alternative to build the project.<sup>12</sup>

In situations of high uncertainty about future traffic levels, this second type of auction shares exactly the same limitations as the one based on bids for tolls. As it can be observed in expression (16), individual expectations  $Q_i^e$  enter the calculations of bids for payments. Thus, the bidding function  $Z(I_i)$  is transformed to be  $Z(I_i, Q_i^e)$  and it no longer guarantees that the most efficient candidate is selected. Condition (13) is exactly replicated in the context of this auction: it is possible that an inefficient firm  $j$ ,  $I_j > I_l$ , with a sufficiently optimistic expectation  $Q_j^e > Q_l^e$ , wins the contract.

Why is it observed in practice that the form of auction has an impact on the probability of bankruptcy/renegotiation of concessions? According to empirical results obtained by Guasch (2000), this probability is higher when auctions are based on bids for tolls. Even though our results show that the expected information rent is the same in both cases, the level of risk assumed by the concessionaire in each situation may be quite different. When a payment auction is used, the government sets the toll  $P$ . Meanwhile, an auction based on tolls uses that variable for competition among firms. A possible explanation for the observed fact of different failure rates is that outcomes from the toll auction imply a higher risk (firms make more aggressive offers for  $P_i$  values, lower than the toll  $P$  set by governments). In situations of low traffic, failure rates will be typically higher for concessionaires that assume more revenue risk.

#### 4. Flexible-term concession contracts

Problems suffered by traditional auctions used to award concession contracts for road projects stem from a common feature to all fixed-term mechanisms: traffic uncertainty induces revenue uncertainty. Therefore, bids submitted by firms are ‘contaminated’ by their beliefs on demand, and

---

<sup>11</sup> The ‘revenue equivalence’ theorem (Vickrey, 1961; Myerson, 1981; Riley and Samuelson, 1981) states that, if bidders are risk-neutral, any form used by a seller to auction a good (first- and second-price sealed bids, English or Dutch auctions) yields the same expected revenues. Both types analyzed here are first-price sealed auctions, and the information rent extracted by the winner is independent of the bidding variable is used (tolls or payments).

<sup>12</sup> This is the result of convergence of bids to real values (Wilson, 1977; Milgrom, 1979).

they do not reflect their true costs. Formally, this can be observed by the presence of demand expectations ( $Q^e$ ) on expressions (11) and (16).

The idea of using concession contracts with flexible terms, proposed in the context of roads by Engel et al (1997, 2001) (for a detailed discussion, see Tirole, 1997), aims at breaking this link between demand uncertainty and revenue uncertainty. A flexible-term contract works as follows: firms submit bids for the total revenue that they want to obtain from a concession ( $R_i$ ), expressed in present value at  $t=0$ . The candidate with the lowest bid wins the concession, and this mechanism is therefore called ‘least-present-value-of-revenue’ auction (LPVR).<sup>13</sup>

The concession contract then lives up to the moment when the concessionaire has collected exactly the revenue claimed from. The contract term is thus ‘flexible’, in the sense that, in situations of low traffic, it is automatically extended during the number of years required by the concessionaire to obtain the desired revenue. On the contrary, if traffic is high, annual profits will be larger, and consequently the contract term is automatically shortened.

It is argued that flexible-term concessions based on bids for total revenue eliminate the risk of traffic from concessions, and they guarantee an effective selection of efficient concessionaires. Although it is true that expected outcomes are superior to the traditional auctions (Engel et al, 1997, 2001), the existence of fixed maintenance costs  $M$  that accumulate over the life of a concession may generate difficulties for concessionaires.

In order to see this, consider for simplicity a scenario with no time discounting of monetary flows. Firms participating at a LPVR auction will compute their bids for revenue based on a function  $R = R(I_i)$ , which depends on their true costs  $I_i$ . A firm  $i$  submitting a bid  $R(I_i)$  knows that if it wins the contract, the life of the concession will be:

$$T^e(I_i, Q^e) = \frac{R(I_i)}{PQ^e} \quad (17)$$

The probability of winning the auction with an offer  $R_i$  can be calculated as in (9) and (14), and the problem that each candidate solves to determine its optimal bid is:

$$\text{Max}_{R_i} P_i^e = \left[ [PQ^e - M] \left( \frac{R_i}{PQ^e} \right) - I_i \right] \left( I_{max} - R^{-1}(R_i) \right)^{n-1} I_r^{1-n} \quad (18)$$

The solution to this problem yields the linear bidding function:

$$R(I_i) = \frac{PQ^e}{PQ^e - M} \left( I_i + \frac{I_{max} - I_i}{n} \right) \quad (19)$$

<sup>13</sup> There exist some few real experiences of road projects based on flexible-term concessions. To our knowledge, the first project making use of the idea of automatic contract extensions was a UK bridge project. A well documented experience is the concession of a Chilean highway, awarded through a LPVR auction (Gómez-Lobo and Hinojosa, 2000).

Equation (19) shows the advantages and limitations of the LPVR mechanism. First, the auction's winner obtains some positive expected profits, equal to  $(I_{max}-I_i)/n$ . Therefore, the mechanism is exactly equivalent to the traditional methods, in terms of the size of the information rent that the concessionaire may expect to extract, and this rent goes to zero as  $n$  increases. Second, when all firms share the same belief  $Q^e$  about future traffic, bids for revenue allow the government to select the most efficient candidate, since  $R_1 < R_2 < \dots < R_n$ . Third, if maintenance costs are small compared to total expected revenue  $PQ^e$ , the impact of traffic belief  $Q^e$  on bids  $R_i$  is relatively smaller than it is on bids  $P_i$  or  $Z_i$  (compare expressions (11) and (16) with (19)).

However, only in the limit case with  $M=0$ , it is possible to argue that a LPVR auction fully eliminates the risk of demand from concessions. In that case, bids for total revenue would be equal to  $R_i = I_i + (I_{max}-I_i)/n$ , and consequently they will be completely independent from beliefs about future traffic levels held by candidates. If no fixed maintenance and operation costs exist, the concessionaire knows with certainty that it will obtain a total revenue equal to its claim  $R_i$ . This will achieve the selection of efficient firms to build road projects, and will eliminate the risks of bankruptcy and contract renegotiation.

Empirical data indicate that annual maintenance and operation costs  $M$  are small compared to construction costs  $I$ , but they are not generally negligible when evaluated for the whole life of a road concession. For a typical project with a life of 30-40 years, total maintenance and operation costs may amount up to 25-30% of total project costs (French Highway Directorate, 1999).

## 5. Least-Present-Value-of-Net-Revenue

A feasible solution for the problem that maintenance and operation costs  $M$  create for flexible term concessions is to design an auction where that type of information is searched for. The new mechanism proposed in this work –which will be named as ‘least-present-value-of-net-revenue (LPVNR)– aims for that purpose. This proposal improves the outcomes obtained by auctions based on one-dimensional bids for total revenue, while at the same time keeps the value of being simple.

In order to avoid firms using traffic estimates to compute their offers, the auction proposed is based on two-dimensional bids. Candidates are invited to submit sealed-envelope bids with two values:

1. Total revenue to be obtained from the concession ( $B_i$ ), without including those amounts devoted to cover for maintenance costs.
2. Average annual costs for maintenance and operation of the road ( $E_i$ ).

The aim of the first value is exactly as in the LPVR mechanism: the amount bid for by the winner will determine the life of the contract, which is flexible and depends on the actual level of traffic. The second value tries to extract information about costs  $M$ , by ensuring the concessionaire that each year it will be compensated by the declared cost. During each year of the concession the

government has access to information about the volume of traffic  $Q_t$ , and it can calculate the net revenue  $PQ_t - E_i$  earned by the concessionaire during that period. The concession contract then lasts until year  $T$  when the following condition (valid for a discrete time context) is satisfied:

$$\sum_{t=1}^T \frac{1}{(1+r)^t} (PQ_t - E_i) = B_i \quad (20)$$

In the simple case with constant demand,  $Q_t = Q$  for all  $t$ , and no time discounting, it is possible to obtain an explicit function of the contract term  $T$ , which depends on the actual volume of traffic received by the road, and the bid  $(B_i, E_i)$  submitted by the auction's winner:

$$T(Q, B_i, E_i) = \frac{B_i}{PQ - E_i} \quad (21)$$

Total profits for the concessionaire will then be:

$$P(Q, B_i, E_i) = (B_i - I_i) + (E_i - M_i) \frac{B_i}{PQ - E_i} \quad (22)$$

Expression (22) shows one of the advantages of LPVNR auctions over traditional fixed-term mechanisms used to select concessionaires. If firms submit bids with  $B_i \geq I_i$  and  $E_i \geq M_i$ , it is clear that  $P(Q, B_i, E_i) \geq 0$ , regardless of which is the actual level of traffic that the road receives in the future. Therefore, the concessionaire may always obtain a non-negative level of profit, independently of which is the traffic level  $Q$ . Risks of bankruptcy and contract renegotiation due to low traffic scenarios are fully eliminated. As in the auctions analyzed above, it can be expected that when the number  $n$  of firms participating at an auction is small, the winner will be able to extract some information rent, which will go to zero as  $n$  increases.

Given the fact that, under flexible-term concessions, the mechanism of automatic term extension makes it unnecessary any contract renegotiation due to low demand, firms participating at a LPVNR auction do not have incentives to submit offers lower than their real costs. Using a bid with  $B_i < I_i$  is not a reasonable strategy, because the firm is claiming for a net revenue lower than construction costs. This could easily endanger the financial equilibrium of the concessionaire. On the other hand, a bid with a claim for net revenue higher than construction costs ( $B_i > I_i$ ), and declared maintenance costs lower than true costs ( $E_i < M_i$ ) could be submitted by a firm that considers that the concession is going to end soon. However, this firm would be taking the risk that eventually the traffic level  $Q$  would turn out to be low, which according to (21) will extend the contract term  $T$ . The strategy of declaring low maintenance and operation costs could then result in the firm obtaining negative profits, if  $B_i - I_i < (M_i - E_i) T$ .

Therefore, if the number of candidates  $n$  is sufficiently large, competition among firms for obtaining the concession contract will make firms to submit bids for revenues based on their true construction costs,  $B_i^* = I_i$ , and claim for true maintenance and operation costs,  $E_i^* = M_i$ . 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.

### *Evaluation of LPVNR bids*

The criterion used to select the winner of a LPVNR auction is to choose the candidate with the lowest total expected costs. Since this is a flexible-term type of concession, it is not feasible to determine *ex-ante* the exact life of the contract. Consequently, it is not possible to select with total certainty which offer is the best in terms of total costs. Whether  $T$  to be known, bids could be evaluated according to the rule:

$$\min ( B_i + T E_i ) \quad (23)$$

Although in practice  $T$  is an unknown parameter when the auction takes place, it is feasible to select the firm with the lowest expected costs. In order to do that, a feasible criterion is to pick a reasonable range of possible durations for the contract (e.g. minimum and maximum expected lengths,  $T_0$  and  $T_m$ , respectively, which can be calculated given the particular characteristics of each project). This range will be announced before the auction is held, so that firms know how their offers will be evaluated.

The auction winner will then be the firm with a bid such that its expected total cost is the lowest, according to the rule

$$\min \left( B_i + \frac{1}{(T_{m+1} - T_0)} \sum_{t=T_0}^{T_m} t E_i \right) \quad (24)$$

According to this criterion, the most efficient firm to implement a road project will be selected by using all available information at the moment of the auction. On the other hand, this method forces firms to adjust their bids to the true cost estimates for the project.

The submission of underestimated bids ( $B_i < I_i$ ,  $E_i < M_i$ ) implies that an auction winner risks its future financial equilibrium, because the flexible-term mechanism means that the government only guarantees with the automatic contract extension the coverage of those costs declared in the submitted bids. Meanwhile, an excessive cost overestimation is neither a good strategy for candidates. Although a concessionaire that succeeds in winning a contract with higher than true values may obtain some extraordinary rents, a firm using that strategy reduces its probability of obtaining a contract, since it can be awarded to another firm with a bid based on values more adjusted to true costs.

### *Advantages of flexible-term concessions with LPVNR auctions*

Some advantages of this new proposed mechanism against traditional fixed-term concessions based on toll or maximum payment auctions are obvious. First, a more effective selection of efficient concessionaires is achieved, because candidates do not need to use traffic estimates to compute their bids, so the problem of selection of optimistic bidders is solved. Second, this mechanism eliminates the need to renegotiate concession contracts when actual traffic levels are below expectations, since the contract is automatically extended up to the moment when the firm has obtained the revenue claimed for in its bid.

Another advantage regarding the utilization of road capacity is that, under this mechanism, the government is able to change tolls (within some pre-established range which can be explicitly stated in the concession contract). Thus, it is possible to implement rational pricing policies, by lowering tolls in situations of low demand, and rising them if the road experiences congestion problems.

When unforeseen circumstances make impossible to fulfill the contract (e.g. extraordinary demand decline), renegotiation is much simpler than under traditional fixed-term concessions. When a government wants to recover a fixed-term concession, it needs to negotiate compensations with the concessionaire. These negotiations are usually lengthy and complex, because they involve the evaluation of costs incurred into by the firm, and lost profits due to the anticipated contract termination. Under flexible-term concessions based on LPVNR bids, maintenance and operation costs incurred into are the ones declared by the auction's winner in its bid, while lost revenues can be calculated as the difference between total revenue claimed for and actual revenues collected from tolls up to the end of the contract.

The re-allocation of traffic risk from concessionaires to users achieved by this new mechanism also brings some advantages in terms of lower capital costs for projects. Private investors know that a flexible-term concession is a risk-free investment, because the mechanism of automatic contract extensions guarantees that a firm building a road project is going to be able to recover all its investments, plus the rate of return that it implicitly used when computing its offer submitted to win the contract. Traffic risks and political risks (governments changing the conditions of a contract) are thus eliminated.

Therefore, it is likely that concessionaires with flexible-term contracts will be able to obtain resources in credit markets at lower costs. In the end, this will result in a social benefit, because road project costs can be smaller. Another advantage is that these concessions may introduce some cost-benefit evaluation of roads: in situations of limited public budgets, road projects which are not attractive from a social perspective will neither be attractive for private participation, because if it is perceived that a project will not finance itself even for very long periods, no candidate would be willing to enter a LPVNR auction.

One crucial decision for LPVNR concessions is the discount rate to be used during the life of the contract. Firms should exactly know which are the rules of the game, in order to calculate their offers to submit at the auction. It is possible to choose a fixed-discount rate, to be kept constant

during the whole life of the concession, or a variable rate. A constant rate provides a more stable scenario to calculate future attainable rates of return. However, a problem associated to a fixed discount rate is that may provide incentives for a strategic behavior from the firm to terminate the contract (it could be more interested in breaking the contract and receiving a compensation than in providing services to motorists).<sup>14</sup>

## 6. Conclusions

Road concessions are long-term contracts between governments and private firms. These contracts are designed to promote private participation in the building and operation of roads (specially highways), and they seek to achieve several simultaneous objectives: construction and operation of the project at minimum costs; provision of quality services to motorists; efficient use of existent capacity by adequate pricing policies; expansion of capacity according to social needs; and financial equilibrium of concessionaires.

There are two basic difficulties for a proper operation of a road concession. First, there is asymmetric information regarding project costs, which is usually solved by means of auction procedures to select concessionaires. Second, traffic uncertainty introduces problems in the calculations of bids submitted to those auctions, and it is one of the main causes of road project failures.

This paper has shown that the traditional auction mechanisms used to award concession contracts generate at least part of the problems suffered by concessionaires. Although there exist several alternative types of auctions, all of them share a basic feature: the contract-term is pre-determined before the concessionaire starts operating the infrastructure. This implies that traffic uncertainty translates into revenue uncertainty. In situations of low traffic, revenues are much smaller than expected, which explains the high failure rate of road projects observed in practice. Another reason explaining this fact is illustrated here: traditional mechanisms do not ensure that the most efficient candidates are selected.

Flexible-term concessions for road projects, in the line suggested by Engel et al (1997, 2001) are a solution to these problems. The basic idea is guarantee concessionaires that they will be able to recover their investments, plus a normal rate of return, by adjusting the contract term according to demand conditions. However, the existence of maintenance and operations costs which are of fixed nature, that is, independent of traffic levels, generates a problem for flexible term concessions, because these costs accumulate over time. Therefore, situations of low demand mean that maintenance costs may erode expected profits, or even generating losses.

---

<sup>14</sup> In the case of the Chilean toll-road concession Santiago-Valparaíso-Viña del Mar, auctioned by LPVR, the winner was offered the possibility of choosing a fixed or a flexible rate for discounting. The concessionaire opted for the fixed rate.

A solution is proposed in this paper, based on the idea of flexible-term concessions complemented with an auction with two-dimensional bids. Firms are invited to submit offers with claims for total revenue, net of maintenance and operation costs, and an annual estimate of those costs. The mechanism ensures the firm that its declared costs will be covered, and that it will obtain the desired revenue. This auction exhibits good properties, which overcome many of the problems suffered by traditional concessions: traffic risk is eliminated, efficient candidates are selected, and there is no need for contract renegotiation in situations of low demand. Therefore, it is expected that concessionaires holding this type of flexible-term contracts awarded by LPVNR will be able to obtain resources in credit markets at lower capital costs, which will result in a higher level of social welfare.

## 6. References

- Beato, P., 1997. Road Concessions: Lessons Learned from the Experience of Four Countries. Inter-American Development Bank, Washington.
- Engel, E., Fischer, R., Galetovic, A., 1997. Highway Franchising: Pitfalls and Opportunities. *American Economic Review* 87 (2), 68-72.
- Engel, E., Fischer, R., Galetovic, A., 2001. Least-Present-Value-of-Revenue Auctions and Highway Franchising. *Journal of Political Economy*, 109, 993-1020.
- Fishbein, G., Babbar, S., 1996. Private Financing of Toll Roads. RMC Discussion Paper Series 117, World Bank, Washington.
- French Highway Directorate, 1999, Analysis of Highway Concessions in Europe. Ministry of Public Works, Transportation and Housing, Paris.
- Gomez-Ibañez, J.A., 1997. Mexico's Private Toll Road Program. Mimeo, Kennedy School of Government, Harvard University, Case Study C15-97-1402.0.
- Gómez-Lobo, A., Hinojosa, S., 2000. Broad Roads in a Thin Country: Infrastructure Concessions in Chile. Policy Research Working Paper 2279, World Bank, Washington.
- Guasch, J.L., 2000. Impact of Concessions' Design in Sector Performance: An Empirical Analysis of Ten Years of Performance. Mimeo, World Bank, Washington.
- Klemperer, P., 1999. Auction Theory: A Guide to the Literature. *Journal of Economic Surveys* 13, 227-286.
- Milgrom, P.R., 1979. A Convergence Theorem for Competitive Bidding with Differential Information. *Econometrica* 47, 679-688.
- Milgrom, P.R., 1989. Auctions and Bidding: A Primer. *Journal of Economic Perspectives* 3, 3-22.

- Mohring, H., Harwitz, M., 1962. Highway Benefits: An Analytical Framework. Evanston III, Northwestern University Press.
- Myerson, R.B., 1981. Optimal Auction Design. *Mathematics of Operations Research* 6, 58-73.
- Newbery, D.M., 1989. Cost Recovery from Optimally Designed Roads. *Economica*, 56, 165-85.
- Nombela, G., De Rus, G., 2001. Auctions for Infrastructure Concessions with Demand Uncertainty and Unknown Costs. Working paper, University of Las Palmas. (downloadable at [www.fcee.ulpgc.es/~gderus/](http://www.fcee.ulpgc.es/~gderus/))
- Riley, J.G., Samuelson, W.F., 1981. Optimal Auctions. *American Economic Review* 71, 381-392.
- Tirole, J., 1997. Comentario a la propuesta de Engel, Fischer y Galetovic sobre licitación de carreteras, *Estudios Públicos (Chile)* 65, 201-214.
- Vickrey, W., 1961. Counterspeculation, Auctions, and Competitive Sealed Tenders. *Journal of Finance* 16, 8-37.
- Wilson, R., 1977. A Bidding Model of Perfect Competition. *Review of Economic Studies* 44, 511-518.