Towards a general model of highway tolls

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Abstract. New relationships could be proposed between public Administration and highway private operators to achieve a coherent and socially accepted global model of toll highways. The new model considers highways licensee firms as transport operators in an “interested management” regime, so that tolls would be defined as a function of level-of-service offered by the highway in comparison to alternative roads, and in relation to congestion rates in metropolitan areas. Tolls would be not a financial mechanism anymore, but a variable fare that the user pays as a reflection of time savings, the increase of travel time regularity, the increase of safety and comfort, etc. In a way, the tolls would represent a price for a service received by the users. The roles of private operators and the public Administration have to mutate too, into what is already being called “public-private partnership”.

1. INTRODUCTION

The existence of a complete highways network, adequately managed and maintained, and with sufficient capacity, is essential for the good progress of a country’s economy. In this sense, the correlation between road mobility indicators and wealth indicators has been fully demonstrated (see, for example, studies for some Spanish highways in Grau, 2001). But, despite the fact that European countries have considered the investments in road infrastructures a priority, public resources nowadays available are lower than those considered necessary for several reasons (European convergence, other social priorities, etc.) and this has led to the complementation of public investment plans with capital furnished by the private sector (European Communities Commission, 2001).

Historically, private highway operators have managed toll segments of highways as license holders. Highway operating licenses have been interpreted as a merely financial mechanism. This system, in the beginning, was accepted as a “lesser evil” to prevent holding back the economical development of the country. However, as more than thirty years have passed since the first private operating licenses went into effect in Spain, the need for renewal (and reinvention) of the existing highways model has become obvious.

2. DEFINING AN ECONOMICAL MODEL FOR HIGHWAYS MANAGEMENT

2.1 The role of the participants

The theory of the principal and the agent allows the analysis of contractual relationships between transportation operators and the appropriate public authority. This economical theory studies how a principal (businessman) can design a compensation system (a contract) that motivates an agent (employee) to act in the principal’s interest. In the management of roads offering high level of service, the role of the principal is performed by the appropriate Administration and that of the agent, by transportation operators (licensees). According to this theory, both the Administration and the service operator seek their maximum profit from the maximization of their utility functions taking into account several variables.

In the world of transport, this theory has been developed and applied to public transport contracts. But in the case of a more economically favorable environment than that of urban public transport (micro-economy prescribes a
structurally inherent deficit), as could be the case of high level-of-service highways, not only must methods for economical compensation be designed for the Administration to palliate losses, but a system must be considered of taxes to be paid by licensee companies when having higher benefits.

Starting from here, the need for a change of mind set, not only of the various administrations and operating companies, but also of highways users is considered. To achieve an optimal operation of the transportation network, the classical concept of toll highways may evolve from its current interpretation of a financial mechanism to that of a transport operator with an interest in serving users.

The first step needed to impose the perspective of a service to users is to separate the tolls from the concept of highway financing (Robusté, 1999). This step becomes even more necessary in countries like Spain where there exist high-level-of-service highways some of which are toll, and some of which are toll-free, but are otherwise similar in technical characteristics.

It is difficult to plan a model that could be perceived as rational without achieving this shift in concepts, because one of the obstacles to overcome is to change the existing understanding of highway operating licenses as financial solutions to budget restrictions. It is necessary, then, that tolls not be perceived as payment for supporting financial costs and a means of obtaining a certain profit, but rather that they must be a payment received associated to a level of service provided.

The user must become aware of two fundamental aspects:
- using the highway entails some costs, and not only the economical-financial kind but also social costs, and
- passing through a certain infrastructure with some established quality and safety levels is a received service and this service has a price that must be paid (assuming some minimum services are granted by the public Administration as a matter of social equity).

The license holding company, in turn, must take into account that they:
- are providing a service to some users and that, as such, must guarantee a pre-set quality level, and
- have the right to seek profit through their practices but while continuing to respect fulfillment of strict requirements, rules and limitations agreed on with the Administration.

The Administration might consider that:
- the application of a highways operating model must be coherent, harmonic and global in order to avoid provoking offense by comparison not only at an interregional or inter-state level but also at an intra-regional or intra-state level or even among users,
- the model must be sustainable and, as the European directives on the transportation field point out (see European Communities Commission, 2001), the income proceeding from pricing can constitute a stock of financial resources some of which could be used to invest in making other infrastructures, especially of railways and public transport,
- it must define and regulate the quality of service to meet the expectations of both highway users and society-at-large because an efficient, good quality transport system is a visible symbol of the country’s good economy, and
- it must improve its collaboration with private license operators by specifying and clarifying business expectations and motivating the private sector toward the continual improvement of service.

2.2 Tolls as a manager of the high-level-of-service road network and as mobility manager

If the toll fee is directly detached from the infrastructure and is associated to the service received by the user, tolls could be set according to other criteria, for example:
- Time saved between the toll highway and the alternative road.
- Increment of safety between toll highway and alternative road.
- Increment of regularity of travel time between toll highway and alternate road.
- Use (intensity/capacity) of the toll highway and the alternate road.
- Change of vehicle flow rate (congestion rate).
- Network effect.
- Multi-modality (mobility options with other ways of transport).
- Vehicle flow, mobility typology and reasons for traveling.
- Economical development of the area.
- Cost-saving associated with avoiding congestion and externalities (social costs).
- Social profitability of the toll highway compared with the alternate road.
- Etc.

We suggest, then, a fee based on the differential characteristics of the high-level-of-service roads in comparison to those offered by the alternative road and by applying congestion rates in metropolitan areas. This way, if we further simplify by considering only the best of all the possible alternatives, a toll fee (rate \(\text{€/km}\)) is obtained according to the difference in quality of services between the highway and its best alternative (\(\Delta\text{performance}\), in terms of difference of costs: time saved, increment of safety between toll highway and alternative road, etc.) and according to the vehicle flow rate for metropolitan areas (Flow) as shown in Fig. 1.a. This figure shows how the fare increases according to a polynomial function of grade 4 to very high levels when the difference in level of service between both options is great. In this case, the alternative is not “reasonable” and a fare reduction must be modeled from a threshold of the difference in level-of-service (Fig. 1.b) to prevent the fare increase on the toll road rising so high as to divert even more trips to the alternate road that is already near collapse.

![Fig 1. Modeling of toll fare (€/km) according to the difference in quality of service between toll highway and its best alternative (\(\Delta\text{performance}\)) and according to the traffic flow (Flow). (a) without diminishing the toll when the alternative is “unreasonable” (not proposed) (b) diminishing the toll when the alternative is “unreasonable” (proposed)](image)

Therefore, the fare must increase according to the difference in quality of service provided between the toll highway and its best alternative until achieving a situation where the alternative offers very low quality service with regard to the highway and, after a flat threshold (for sensibility and perception purposes) where the maximum fare is reached, if difference in quality of service continues to increase, the toll is progressively reduced to balance flows along the whole corridor. This consideration makes it possible to achieve situations very close to the social optimum in every travel corridor.

These criteria would allow the use of tolls as a manager at two levels:
- Tolls as manager of high-performance road network, would allow the application of compensations between license renewals. This way, operating licenses that are new and must endure huge costs derived from construction and initial financing could receive contributions from more mature operating licenses generating large profits.
- Tolls as mobility manager for the whole transport system in which the fare value (variable in time) regulates user’s modal choice and makes it possible to obtain a totally sustainable transport as user pays externalities he causes, and at the same time, enables finance for public transport with part of the fares from the high level of service roads.

For its optimal management, it would be necessary the establishment of a consortium of appropriate Administrations and licensee companies for a certain geographic delimitation where the new relations would be specified, including construction costs and prevailing traffic demand.
2.3 Need for an Authority

Given the previous considerations, in order to ensure that the high-performance road network and, in general, the mobility of the whole transport system is managed in a united and integrated way, an entity or controlling consortium has got the role of monitoring the quality of the service offered in the sections of road operated by the licensee firm, and to survey the whole network, such as the Transport Authorities do for transit licensees. Thus, just as the fares paid by users of the transit network are not related directly to the construction cost of the segments they travel, the tolls paid by users of the high-performance road network should not relate (more than a percentage) to that reason either.

The creation of such a controlling authority would allow, on the one hand, proper regulation and standardization of criteria and conditions in each section of the network and, on the other hand, would make it possible to establish economic compensations (drawn from surpluses in the case of operations showing a certain level of profit) for sections showing a financial deficit.

2.4 Formulation of the economical and financial model

2.4.1 Guarantee of financial balance

The change in the way tolls are conceived of must have a solid economical basis, allowing minimally that none of the agents involved be damaged, or preferably, that all them profit. Firstly the establishment of a financial balance is necessary for private companies to obtain profitability from their investments at moderate risk (profit for operators) while working with low toll rates (profit for users) and in performing the maintenance and operation according to the quality criteria agreed upon with the Administration (controlling authority). The guarantee of financial balance diminishes the risk involved in the existing licenses (“at own risk” licenses) offering the investor greater safety because the system reverts resources to the licensee in the case of losses— but also limits profits—being more similar to operations based on preset profits.

It is possible to formulate an idealized case, enough to set forth the basic concepts. An investment \( I(Q^o) \) is instantly made in year 0 and depending on a minimum quality level \( Q^o \) fixed by the Administration through the controlling authority. The annual costs of management and maintenance are considered such that for every year \( j \) they are \( m_j(q_j, Q^o) \), a function of traffic flow \( q_j \) and quality standards \( Q^o \). This quality level must respond to a social optimum and depends on the quality of life that the application area (region, state, nation) wants to or can afford.

The mentioned costs can be updated to a fixed discount rate that does not contribute any conceptual improvement and, to make things simpler and without loss of generality, is supposed to be zero. Nonetheless, when developing applications of the proposed model it will be essential to take into account all the simplifications made to clarify the notation and properly quantify them. On the other hand, for purposes of notation, toll variations according to traffic cannot initially be distinguished.

The operating period is \( T \) years (variable period) and \( \tau_j \) is the optimum toll rate for year \( j \) from the previously calculated social point of view. The condition for the licensee balance is that in an accumulative way over the \( T \) years, the traffic, the fixed quality level, profits \( B^o_j \) expected by the operator in year \( j \) and the costs of investment and operation-maintenance could allow the generation of surpluses or net incomes. And if not, the Administration contributes with a shadow toll \( \sigma_j \) (that in the cases of financial imbalance favorable to the operator could be negative, that is to say, a collection shaped like a tax) that guarantees financial balance. In a simple way, this balance can be described by the following expression:

\[
I(Q^o) + \sum_{j=1}^{T} m_j(q_j, Q^o) + \sum_{j=1}^{T} B^o_j = \sum_{j=1}^{T} (\tau_j + \sigma_j)q_j
\]  

[1]
2.4.2 Update value of net incomes

This model proposes using a Net Present Value of Revenues (NPVR) (De Rus and Nombela, 2000) as expression of the usual concept of Net Present Value (NPV) in the evaluation of investment with Cost/Benefit analysis:

\[ NPVR = \sum_{j=1}^{T} \left( (\tau_j + \sigma_j)q_j - m(q, Q^o) \right) \]  \hspace{1cm} [2]

On one side, \( NPVR \) represents the addition of the initial investment \( I(Q^o) \) to be made and the accumulated profits until the end of the license period that the private operator expects to obtain (obviously, guaranteeing the fulfillment of the financial balance). On the other side, as is shown in equation [2], it represents the addition of the difference between incomes for all the annual payments of the license operator (direct fares \( \tau \) and indirect fares or shadow tolls furnished by the controlling authority \( \sigma \)) that is equivalent to the addition of the annual profits of the operator, deducting the initial investment \( I(Q^o) \).

For a given value \( NPVR^* \) the term \( T^* \) of the concession depends on the traffic flow \( q_j \). With this model there is no need to make a traffic demand forecast for the high-performance road in question, because the Administration has agreed on the \( NPVR \) in the contract, independently from reaching this value over a long delay of time or a short one (De Rus and Nombela, 2000).

With the application of this model, efficiency would be motivated by controlling unitary costs of operation and maintenance and offering annual allowances (that do not enter the accounts on net update incomes) according to the quality increments (objective and perceived) achieved. Penalizations would be also considered if there were a noticeable decrease in quality. These \textit{bonus} and \textit{malus} are controlled (regulated) and executed by the Administration that approved the license concession.

3. CONCLUSIONS

The bases have been formulated for a model considering license holders of toll highways as transportation operators in an “interested management” regime so that tolls are defined by differential performance between the toll highway and the alternative roads, and with respect to congestion rates in metropolitan areas. The Administration monitors costs and the quality of service of the private operator using objective indicators of quality.

The rate is not applied as a strictly financial mechanism, as is the current practice, but rather the user would pay a variable toll corresponding to the payment of social costs for externalities and to differential performance in relation to reasonable alternatives.

The proposed model, through the partial contribution of the Administration in tolls (or by collecting a tax, depending on the case) to guarantee financial balance, makes it possible to consider high-performance roads at a level of network rather than each license concession one-by-one. This allows achieving situations close to the social optimum without giving up reasonable industrial profits for operators and with a lower investment risk than the present one. In a word, the model starts to develop what it is being already called “public-private-partnerships” (PPP).

ACKNOWLEDGEMENT

The author thanks the contributions of Carles Vergara and the information provided within the framework of the Working Group for highway tolls created by the Parliament of Catalonia, Spain.

REFERENCES


