Proactive Charging Schemes for Freight Transport: Dynamic Toll Discounts as a Tool to Reduce the National Roads Traffic

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ABSTRACT. *In the present context, urban and national road networks are frequently highly congested in many European countries, resulting in increased travel times and delays. At the same time, some highway networks, particularly in Portugal, have a good quality although they are underused infrastructures due to the toll charges. The implementation of dynamic charging on highway networks can contribute towards the optimization of the network performance.*

Logistic operators are one of the national road networks main users and thus understanding their behaviour is of vital importance for the development of any dynamic charging toll model. Within this context one of the pilot cases of OPTIMUM project (www.optimum.eu) involves the development of a forecasting and dynamic (toll) charging model with the key objective of transferring heavy traffic from the urban and national roads into highways.

KEYWORDS: *dynamic charging; OPTIMUM project; heavy traffic; toll prices*

1. Introduction

Urban and national road networks are the main ways of connecting the different cities from different countries within Europe, as result they became in the past few years severely congested, resulting in increased travel times, increased number of stops, unexpected delays, greater travel costs, inconvenience to drivers and passengers, increased air pollution and noise level, and increased number of traffic accidents occasionally involving pedestrians as those roads crosses many settlements.

At the same time, a high number of highways arise in several countries – particularly in Portugal –, that, in some cases, became highly underused due to the introduction of the toll charging. Portuguese drivers declare that they prefer to use free roads, disregarding safety, travel times and other aspects, and basing their decision making process only on toll prices. This fact is leading to a more intense use of the national roads network from the one that they were initially projected for, increasing maintenance costs, pollutants emission and reducing safety and comfort for users.

Therefore, the implementation of a dynamic pricing on highway networks can reduce congestion by moving some traffic demand from national roads, to provide users with the option of alternating journey times or using different transport modes, by eliminating trips or by transferring traffic demand from the national roads into highways, as well as it will be making the economy moving as the return of investment will be taking place.

Since logistic operators are one of the national road networks main users, which repeatedly request flexibility in tolls pricing, and since heavy trucks are the main generators of the highways revenues (Sun et al., 2013), their options can have a strong impact on the system.

Thereby, the European project "OPTIMUM – Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility" (www.optimum.eu) considered a pilot case that involves the development of a forecasting and dynamic (toll) charging model

This paper will present an analysis of the current situation in Portugal's road network (traffic flows, toll charges, etc.) and the methodological framework developed for OPTIMUM pilot.

2. Literature review

2.1. *Implemented charging models and dynamic pricing*

In Europe, since 2001 that several cities already adopted 'congestion charge' schemes, mainly to combat congestion and/or environmental problems. Most of these cities have adopted constant prices during the day, however there are exceptions as the case of Sweden, which the amount of tax payed to enter and exiting central Stockholm varies with the time of day that the driver enters or exits the congestion tax area.

In the United States of America (USA), one of the most prevalent solutions regarding dynamic pricing is the adaptation of the high-occupancy vehicle (HOV) lanes to high-occupancy toll lanes (HOT), which consist in allow lower-occupancy vehicles to pay a toll to gain access to the HOV lanes (Lou et al., 2011). These systems were first implemented in 1995, and aim to avoid the underutilization of the HOV lanes and generate additional revenues (Jang et al., 2014).

To achieve the objectives efficiently, toll prices should be adjusted in real time, as a response to changes in traffic (Lou et al., 2011). This is what happens, for instance, in the dynamic toll implemented in the “fast lane” of the highway between Jerusalem and Tel Aviv (Israel), based on an algorithm developed by Siemens, ensuring that the dedicated lane’s capacity is sufficiently used while preventing traffic jams: when traffic is light, the toll fee drops, and when traffic gets heavier, the fee increases.

2.2. *Highway traffic and trucks’ route choices*

Some figures are presented in a report to a JP Morgan evaluation (Bain, 2009) that stated that only one out of 14 toll roads exceeded its original revenue forecast. In four projects, the real revenues were about 30% lower than the forecasts.

Part of the reasons to have lower revenues may be due to the errors in trucks forecasts (mainly made of over-estimations of drivers’ or companies’ willingness-to-pay tolls): references shows that, a number of toll roads have experienced much lower truck usage than initially predicted (Bain, 2009). Over estimations on heavy traffic also leaded to serious over estimations in revenues, since trucks pay a much higher tariff than passenger cars.

However, truck trips and their route choices are not driven by the same reasons that car trips: the route choices are, in many cases, assigned by the fleet operator, which may (or not) decide to avoid toll roads or give them the preference, independently from the driver willingness-to-pay. Sometimes, the routes are only recommended, allowing drivers to ask for an approval to change or choose another one (from a set of alternatives or to make their own choice) (Sun et al., 2013).

2.3. *Current Situation in Portugal*

2.3.1. *Highways network evolution*

The first section of Portuguese motorway was built in 1944. By 1961 the network consisted of 32 km of motorways, 24 km being subject to a toll charge. The first highway concession has been awarded in 1972, and in 1985 the national highway network had an extension of only 158 km. The adhesion of Portugal to the European Union (EU) in 1986 generated a significant increase on road traffic, making the reformulation of the existing National Road Plan (PRN2000) imperative.

In 2014, there were about 3.000 km of highways in Portugal. According to the Portuguese institute of road infrastructures (that uses Eurostat data), Portugal was, a few years before, one of the European countries with more highway kilometres per million of inhabitants, only surpassed by Slovenia, Cyprus, Spain and Luxembourg. In terms of density, Portugal was also one of the European countries with higher values: 34 km/1.000 km².

However, even with a high-quality and high-density network, more than 60% of the highway extension had average annual daily traffic (AADT) values lower than 10.000 vehicles/day. For this reason, about 94% of the highway network registered a level of service (LOS) of “A” or “B”, representing a clear situation of underused infrastructures.

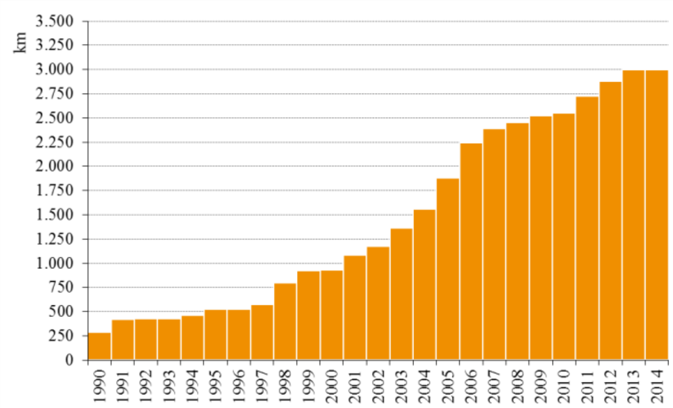

Figure 1. *Portuguese highway network evolution between 1990 e 2015(by number of kilometers). Source: APCAP and Infraestruturas de Portugal*

2.3.2. *Toll collection*

In 2013, the vast majority (about 84%) of the highway network in Portugal had tolls. There can be identified two different toll collection approaches in Portugal: cash booth or electronic toll collection lanes (physical toll plazas on every entrance and exit of the highway) and electronic toll collection, using the Multi-Lane Free Flow System (MLFF systems) (which consist in toll gantries installed on some specific highway sections).

Most of the MLFF systems were installed after 2010, and allow three different types of payment: electronic toll collection using an onboard unit (like Via Verde); video tolling collection, with post-payment at the post offices, online or ATM (only available for national plates) and electronic toll collection with pre-payment (only available for foreign plates) using EasyToll (association of a credit card like MasterCard or Visa to the license plate of the vehicle), Toll Card (“on the shelf” product with a fixed amount to be consumed and that is activated through a SMS), prepaid ticket (with unlimited use for 3 days, 20€, or previously defined journey – round trip from Spain to Porto Airport or round trip from Spain to Faro) or temporary “Via Verde” onboard unit (rental option for weekly periods).

This tolling scheme is applied to highway sections and bridges, and to all types of vehicles. The "base tolling tariff" is a fixed value set on every concession contract, annually updated in the first month of each calendar year according to a calculation mechanism based on of the CPI (Consumer Price index), and also defined in the contract.

The toll is set for each type of vehicle (there's a 4 types classification established, being the tariff fixed for "class 1" and then applied multiplicative factors, also defined on contracts, for the others classes), based on the distance to charge. Any change (new values, discounts or free payment rules) must be approved by the Portuguese Government. In accordance with the current legislation and concession contracts, and in order to ensure the public interest and the provision of a better public service, the Government may define that the toll rates vary depending on the particular time of day, special areas, number of passages of the same vehicle or vehicles class, for instance.

With the introduction of tolls collection (MLFF) on some existing (not-payed) highways since 2010, Government decided to implement a positive discrimination scheme for local population and companies, minimizing the impact of that policy measure (10 first trips of the month (per highway) were free and a 15% discount on the following trips (on the same highway)). That scheme was applied until October 2012, when the Government decided to implement instead a 15% universal discount in a highway specific sample that is still in force.

In February 2012, it was set by the Government a special discount for Heavy Goods Vehicles (HGV). This measure is consistent with the principles set out in the "Eurovignette" Directive, allowing the optimization of the use of road infrastructure, promoting road safety and minimizing damage to the infrastructure and environmental damage. When travelling on that same highways where in force the 15% universal discount (and only on those), HGV can take advantage of: 10% discount on the value of the toll rate during the day (07 - 21h) and 25% discount at night (21 - 07h) and weekends.

3. OPTIMUM Project: the Portuguese pilot case

3.1. *The consortium*

At this stage, the Portuguese pilot case is being built by five of the OPTIMUM project consortium members: Infraestruturas de Portugal (IP) – the National Authority with traffic management and traffic information role on the Portuguese road network; Luís Simões (LS) – a Portuguese freight company (transport and logistic operator) that is the leader in road transport in Portugal and in the Iberian flows; Transportes, Inovação e Sistemas (TIS) – a consultancy company specialized in mobility and transport, providing services in areas related to transport economics, logistics, energy and environment, sustainable mobility, public transports, traffic engineering, urban and regional development and regulation and policies; UNINOVA – a multidisciplinary research institute with high experience in international research programmes; and University of the Aegean (UA) – a growing and innovative public high education and research institute.

3.2. *Methodology*

The methodological framework is presented on Figure 2. There are two main tools for this pilot case: the traffic model to be developed by TIS and the econometric model to be developed by UA. Both models will contribute to evaluate the trucks' route choice facing the discounts that should be applied to the tolled roads.

IP is the main data provider for both models, since they can provide traffic speeds on the highway and national roads, toll prices per class and booth on the highway and historic hourly traffic volumes on the highway and national roads. Luis Simões also works as data provider, since their usual trips were also analysed, while UNINOVA has the task of "data harmonization".

The traffic model, used by TIS for all over the past decade and enhanced by the new data sent by IP, will help UA to calibrate their econometric route choice model. As result from the model, a toll discount should be calculated based on the historical data and the forecasted traffic conditions, and for each heavy vehicle class and highway segment.

To verify the efficacy of the dynamic pricing scheme (as a kind of calibration of the econometric model), Luís Simões will test the designed model, choosing (or not) the path with the discount. This will allow, in the first place, to obtain more accurate references for the "Value of Time" (VoT) and the "Value of Distance" (VoD) and, in the second place, the estimation of the transferred traffic from the national roads.

Luis Simões will test the model by using 10 trucks in the real network but with toll prices fixed by the model and the route choices made by the company will be monitored, evaluating if the toll values are leading to a transfer traffic from national roads to highways.

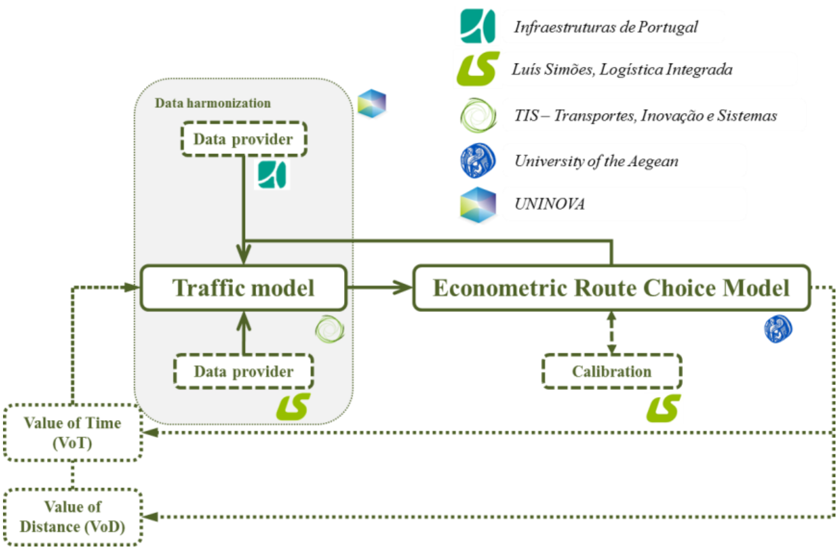

Figure 2. *Methodological framework of the Portuguese pilot case.*

3.3. *Traffic model*

The traffic model developed by TIS and updated in a yearly basis (last update occurred already in 2016) has been widely used and it encompasses the entire Portuguese road network, although the pilot case regards a smaller area from the North/Center region

The pilot network was defined taking into account the routes used by Luis Simões on their daily activity and the highways where data could be provided and which belong to IP concession. Therefore, the network contains two connections to the Portuguese border with Spain (A28 and A25) and the network surrounding the urban area of Oporto (A29, A41, A4, A43), the second biggest city in Portugal. Together with these highways, the pilot network is also composed by the national roads that are used by Luis Simões as a free alternative to the payed highways.

For each alternative route, the generalized cost of the trip is calculated, which is used as the "utility" to distribute demand between different routes. Within the assignment procedure, the travel cost on each road link is based on the value of time, value of distance (also called vehicle operation cost) and toll cost.

The adopted equation to determine generalized cost, as perceived by drivers, is as follows:

$$C = L \times VoD + T \times VoT + L \times P \qquad [1]$$

Where C represents the cost (€), L the trip length (km), VoD the value of distance (€/km), T the trip travel time (s), VoT the value of time (€/s) and P the toll price (€/km).

For the calculation of the Value of Time (VoT) a methodology was set based on the conclusions from European projects and afterwards updated to the Portuguese context and the 2015 economic reality, resulting in a preliminary value of 44,02 €/hour for the heavy vehicles. For the calculation of the Value of Distance (VoD), some elements have to be taken into consideration such as the cost of fuel, oil, tires and vehicle maintenance. At the end VoD was estimated to an average value of 0,258 €/km for the heavy vehicles.

3.4. *Data collection methodology for route choice*

In this section, it is presented the data collection methodology for understanding the behaviour of logistics operators and truck drivers towards route choice. An online questionnaire has been developed through which both revealed and stated preference data will be collected. In the below sub-sections the questionnaire developed will be presented.

A questionnaire was designed specifically for this research and made available on the web. It includes two sections. Section 1 refers to the characteristics of the most usual/common shipments that the company/driver transports, the factors affecting route choice, use of electronic tag for tolls, basis for calculating compensation and acquisition of travel related information.

In Section 2 the participants are presented with stated preference (SP) scenarios for a variety of route alternatives. The SP scenarios were also designed specifically for this research and include two alternative routes: National (non-toll) and Highway (toll road). The attributes included in the SP scenarios are total travel time from origin to final destination (in minutes), fuel cost (in Euro), toll (in Euro), and a variety of incentives that the toll users may be benefited from by choosing the alternative road. Table 1 below presents the list of incentives with their respective levels.

In order to avoid misperceptions and to assure that the choice requested is clear to all the participants it was decided to use pictures of the actual routes. The pictures were carefully chosen ensuring that they would be easily understood by the participants. After the selection of the attributes and the attribute levels, 150 different scenarios were generated, in which the order of the attributes was randomized. At the end, each respondent will be presented with eight scenarios. In Figure 3 and Figure 4 it is envisaged to present an example of the stated preferences (SPs) that will be used for the analysis and modelling in this pilot.

Table 1. *List of incentives for toll road alternative.*

A/A	*Incentive*	*Levels*
1	*Discount in fuel price*	*0 to 40%*
2	*Higher speed limit*	*0 to 20 km/h*
3	*Real-time travel information*	*Yes or No*
4	*Dedicated truck lane*	*Yes or No*
5	*Rest area for drivers/diner*	*Yes or No*
6	*Overweight bypass*	*% of actual weight*
7	*Off-peak toll discounts*	*0 to 25%*

Figure 3. *Stated Preference Example Screen (i).*

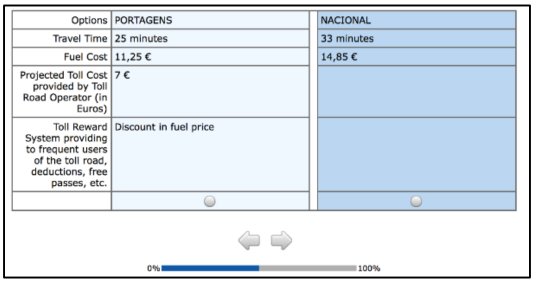

Figure 4. *Stated Preference Example Screen (ii).*

4. Conclusions

This discount information will be assisting the logistic operator, with 48 hours in advance (allowing the planning procedures), in their decision making process of choosing the highway with the new toll price instead of the national road.

The system is in its first "baby steps" but it is this project's conviction that in a near future it will be the chosen option not only for logistic operators but for the common citizen that may at a certain moment decide the route that suits better their needs.

This model can also be of important assistance to all the apps that are currently being developed to prevent congestion in the roads and provide to users a pleasant journey time without delays and bringing the benefits of using dedicated road networks such as highways.

The objective must be a "reactive self-learning approach": the revealed willingness to pay should be gradually learned by the system (Lou et al., 2011), not only regarding the "new" traffic and weather conditions that should be constantly read by the models, but also regarding the understanding of the behaviour of the truck operators in response to the potential toll discounts.

5. References

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