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Do PPP contracts improve road safety?

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DO PPP CONTRACTS IMPROVE ROAD SAFETY?

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ABSTRACT

Public Private Partnerships (PPPs) are mostly implemented for two reasons: to circumvent budgetary constraints, and encourage efficiency and quality in the provision of public infrastructures. One of the ways of reaching the latter objective is by the introduction of performance-based standards tied to bonuses and penalties to reward or punish the performance of the contractor. These performance-based standards often refer to different aspects such as technical, environmental and safety issues.

This paper focuses on the implementation of safety-performance incentives in PPPs. Although safety depends on causes that are hardly manageable by the private contractor (user behaviour, characteristics of the vehicles and so on), there are still some factors—mostly related to the design, maintenance and operation of the infrastructure—that are manageable by the contractor. These factors may play an important role in the improvement of road safety, which may contribute to reduce risk situations and diminish the severity of accidents.

The aim of this paper is twofold. First, we intend to analyze and classify the explicit safety incentives implemented up to now in motorway PPP contracts across Europe. And second we intend to identify whether the incentives to improve road safety in PPPs are ultimately effective in improving safety ratios. To that end we have calibrated several econometric models using information of toll motorways in Spain.

We found that only few countries in Europe are implementing explicit incentives that reward the contractor in terms of the safety outcome. In addition, we realise that the indicators used to measure the safety outcome and the incentives offered to the contractor diverge substantially across European countries.

Moreover, we found that, even though road safety is highly influenced by variables that are not much controllable by the contractor such as the Annual Average Daily Traffic (AADT) and the percentage of heavy vehicles in the motorway, the implementation of safety incentives in PPPs has a positive influence in the reduction of accidents because this variable is significant for all the calibrated models.

INTRODUCTION: ROAD SAFETY IN ROAD MANAGEMENT

The improvement of road safety remains a main objective for developed countries. Only in the European Union (EU) 39,000 people lose their lives on the road every year and there are around 1.5 million injuries (European Road Accident Data Base CARE 2008). In fact, involvement in road traffic crashes is the leading cause of death and hospital admission in the EU for people under 45 years. Apart from the suffering of the victims and society, there are many other costs associated with these tragedies such as material damages, loss of productivity and human resources. According to the European Road Safety Action Program 2011-2020 of the European Commission in the EU alone these costs could amount to €180 billions, representing 2% of the GDP.

There are many different aspects that affect road safety but usually these are grouped in three blocks: human, vehicle and infrastructure. The way each of these blocks should be considered as a cause of accidents is a complex issue. Firstly, because the term “cause” is a complex concept. But also because accidents are not the consequence of a sole reason. Nevertheless, the scientific community agree (e.g. Sabey & Staughton, 1980) that human factors are involved in most of accidents while infrastructure and, especially, vehicles influence accidents much less. Anyway, improving vehicles and roads can further reduce their role as trigger factors of accidents and more importantly, they can minimize the consequence of accidents.

ROAD SAFETY ASPECTS OF AN INFRASTRUCTURE THAT ARE MANAGEABLE BY THE ROAD OPERATOR

During the life span of a road, from its initial design, and all through its process of operation, there are decisions that affect road safety. Many of these decisions can only be taken by the Public Sector or must follow rules and regulations. However, a wide range of decisions are left to the discretion of the operator of the infrastructure. The reason why these decisions should be identified is that they can be managed and optimized by the operator if there are enough incentives to do so.

In this respect, the design and operation stages offer most opportunities for the contractor to improve road safety. However, there are some important aspects that, depending on the type of contract, can not be managed within the contract. For instance, the number and type of crosses and accesses to the road are usually decided at the planning stage.

Although the design stage is regulated by technical rules, there is plenty of room to improve road safety with a good design. For instance, it is usually possible to improve safety by looking for better design consistency and avoiding surprises for drivers. This process can be

realised by carefully auditing the project. External audits usually discover undetected faults even when the whole project follows all the regulations. Other important aspects at this stage of the project are the design of the road section and the design of the surface drainage. The friction of pavement surface depends on both road section and surface drainage which in turn lead to road safety. The fact is that in most of the cases these details are completely chosen by the designer.

Furthermore, decisions about road signs and facilities are mostly left to the discretion of the operator during the design stage. In fact, regulations do not usually mention the location and characteristics of many signs and facilities aimed at safer and more comfortable driving. Inside this group we find lighting of road stretches, installation of pavement reflectors, barriers and even the construction of rest areas. In general, the more facilities, the safer the road. However, these facilities usually have a high cost.

During the operation stage there are many safety management opportunities that can be taken advantage of by the contractor. These include the detection and removal of obstacles from the road surface, treatment to prevent the road from icing up, or the treatment of road borders and verges to improve visibility and which are also related to the consequences of accidents. But for all these activities, frequent inspections, human resources and specialized machinery are required to carry out the necessary work. The results depend on the organization and resources available and these depend on the operator and vary from project to project.

Special mention must be made here of the importance of pavement surface maintenance since friction depends very much on this aspect. Apart from the type of pavement surface to choose, cleaning and resurfacing the pavement are important aspects of road management.

The decisions about the updating of road facilities can also be taken in different ways. In this respect, not only does the normal maintenance and renewal of equipment depend on the road operator but also in keeping this equipment technically up to date.

Last but not least, specific attention to accidents is relevant at this stage. For example, arriving quickly at the scene of an accident can be crucial for saving lives. In this sense, there are many possibilities, from the frequency of road inspections, to the monitoring of the infrastructure and also to the amount of resources available to perform these tasks.

OTHER ASPECTS THAT INFLUENCE ROAD SAFETY AND COULD BE MANAGED BY THE PPP CONTRACTOR

There are some other aspects that influence road safety and that could be included in PPP contracts but whose decisions are usually taken by the public sector according to the rules and regulations at the time. Many of these aspects belong to the initial stages of the conception and design of the road. For example, the type of road, number of carriageways, driving speed limits and the alignment of the road are aspects that greatly affect road safety. Nevertheless, all of them are usually decided by the public sector irrespective of the management model. If the PPP contractors could manage these aspects, they would be able to influence safety rates. If the government includes rewards and penalties tied to safety indicators, and at the same time gives freedom to the contractor to manage these aspects, the contractor will have the opportunity to have even more influence on safety ratios.

Traffic management (like ramp metering techniques, lane restrictions for some kind of vehicles at rush hour, etc.) is another field usually not assigned to the contractor in road maintenance contracts. The main reason is because this matter is commonly reserved to the police authorities. In any case, there has been a huge step forward in the techniques for monitoring the road. On the one hand, it is true that the public service of the road must be guaranteed. But a more efficient road safety management can be achieved by fine tuning information and, in some cases, by introducing restrictions on drivers and vehicles.

In general, the inclusion of any road safety aspect eligible to be a performance-based indicator tied to rewards and penalties in PPP contracts should be considered if they are likely to reduce accident rates. Even if the regulations offer limited opportunities to manage road safety, the operator should still be allowed to find ways of including any safety measures not foreseen by the regulations. In fact it would be interesting to study models that left decisions about human and vehicles factors in the management of road safety to the operator.

THE IMPLEMENTATION OF PERFORMANCE-BASED INCENTIVES IN PPPS

Many countries around the world are seeking new means to involve the private sector in managing and financing infrastructure through Public Private Partnerships (PPPs). Three reasons lay behind this trend: the growing budgetary constraints, the search for greater productivity efficiency, and the improvement of quality through a better allocation of risks and incentives (OECD, 2008). One of the most common ways of implementing PPPs in managing infrastructure is through the concession approach, which consists basically in transferring final design, construction, maintenance, and operation of the infrastructure to a

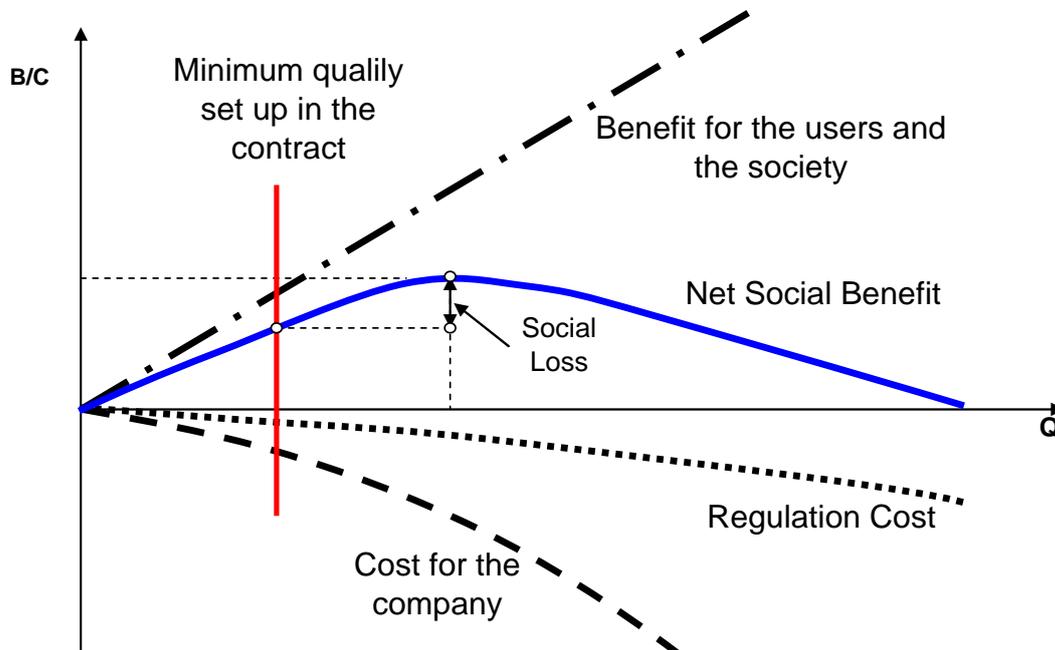
private consortium, in exchange for which that consortium receives the right to charge a fee to the user or to the government on behalf of the user, for a period of time contractually agreed in advance (Vassallo and Gallego, 2005).

Concession contracts should include the necessary provisions in order that the relationship between the public and the private sector work at their best throughout the life of the contract. To this end, the bidding terms and contracts should comply with two requirements: first, ensuring that the most efficient bidder in terms of price and quality will be granted the contract; and second, providing incentives to the contractor to render the highest quality level compatible with a reasonable cost.

One of the key aspects of PPPs is precisely to allow freedom to the private sector to manage and operate the infrastructure in the best way. To that end, in the last few years PPPs are evolving from mere demand-based contracts to service-based contracts. Consequently, the revenues of the contractor tend to depend more and more on performance-based standards rather than on traffic demand. Two reasons lie behind this trend. First, PPP contractors can manage better the service performance they offer than the traffic flows in the infrastructure. And second, encouraging the PPP contractors to provide a better service by aligning the social and the private benefits will end up producing a more efficient outcome to the society.

Figure 1 shows the relationship between quality (x axis) and social costs and benefits (represented in the y axis) for a certain infrastructure. Quality cannot be expressed in units. For this reason, we identify quality with the social benefit produced by it. In other words, a certain quality increment will lead to a proportional social benefit increase (see the double stroke broken line in figure 1). However, providing a greater quality level would imply a greater cost for the private company, which will progressively become greater (see the long-stroke broken line in figure 1). Moreover, a greater quality level would require greater transaction costs in terms of monitoring the contracts (the long-stroke broken line in figure 1). Summing up the three curves, we obtain the “net social benefit” curve, which is coloured in blue. This curve shows that there is an optimum quality level compatible with the ability of the contractor to offer a certain quality level at a certain cost. This optimum is not static, since the better the efficiency of the contractor to provide a certain level of quality the greater the optimal quality level will be.

Figure 1 Optimal quality level



Traditionally, most of the infrastructure management contracts, including PPPs, have not introduced explicit incentives to increase quality. Rather they have usually set up a minimum quality (see the red line in figure 1) in such a way that if the contractors perform below this quality level, they will be penalized; but performance above this level, will not be rewarded. These types of contracts have the problem that they do not incentivize the contractor to reach an optimal quality level. This is the reason why nowadays most PPP contracts are encouraging the introduction of incentives tied to bonuses and penalties to foster the contractor to provide the optimal quality level.

Those performance-based incentives, however, have to be introduced in the right way in PPP contracts. To that end, the marginal reward to the contractor for reaching a certain quality level should never be larger than the marginal social benefit produced at that level. The contractor will provide a quality level at the point where the marginal revenue obtained due to a certain quality increase equals its marginal cost. If the incentives are defined this way, the contractor will be encouraged to provide the best service compatible with its production costs.

The approach explained above has moved many countries to introduce performance-based indicators tied to bonuses and penalties in their PPP contracts. Some countries, such as the United Kingdom has mostly replaced the demand-based approach (Debande 2002) by the performance-based approach. Some other countries, such as Spain, have incorporated bonuses and penalties tied to performance-based standards in many of their PPP contracts (Delgado et al. 2007).

Performance-based indicators have been selected in many countries on the basis of their manageability by the private contractor and their impact on social welfare. Some of the most common standards introduced in motorway contracts are: availability of lanes, congestion, state of the assets, queuing in toll plazas, and satisfaction of the users measured through surveys. Safety results are also considered regularly.

Since the early 90s, the United Kingdom has exhibited great concern for incorporating the private sector in managing public infrastructure and services. Design Build Finance Operate contracts (DBFO) were implemented for the upgrading, maintaining, and operating of already-existing motorways and other infrastructure facilities in the United Kingdom for a period that was to be fixed in advance. The contract terms established that the Highways Agency (the British Authority in-charge of managing the trunk network in the UK) has the obligation of paying the DBFO contractor according to the criteria set up in each contract.

From the beginning, these contracts were largely concerned with infrastructure quality. In fact, the DBFO motorway contracts granted before 2002 established a variable toll depending on lane availability (number of opened lanes, time of day, and type of vehicle) and some coefficients (depending on safety and level of service). Since 2002, new criteria have been applied, based on paying the contractor according to both the combination of traffic flow and the average speed on the motorway. This system was introduced to encourage the contractor to keep a free flow on the motorway by carrying out, for instance, road works during off-peak hours.

In the last few years, Spain begun introducing performance-based indicators in both toll and shadow toll motorways (Vassallo and Pérez de Villar 2010). Toll motorway concession contracts include a provision to extend the contract duration up to four years if some performance-based indicators tied to some quality aspects like queuing in toll plazas, congestion, state of the pavement and satisfaction of the users are ultimately fulfilled. Other PPP's awarded recently in Spain also include incentives in terms of annual bonuses to be incorporated to the periodic fee paid by the government to the contractor linked to performance-based indicators such as availability, state of the pavement and so on. The assessment of road safety as a performance-indicator has also been included in most of the cases in the way described in the next section.

ANALYSIS OF EXPERIENCES IN THE INTRODUCTION OF ROAD SAFETY

INCENTIVES IN PPPS IN EUROPE

In this section we gather the information of how road safety incentives are being introduced in PPP contracts within the EU countries. As a result, we have identified 18 countries with PPP roads (see table 1) and we have collected information of more than 50 contracts.

First of all, it must be pointed out that all the PPPs analysed adopt mechanisms to improve road safety in different ways, but not necessarily through incentives tied to performance-based indicators. The reason is that road safety is always present, in the management of roads, even in an indirect way. In fact, all the contracts introduce conditions related to design, maintenance or operation to achieve, at least, a standard of road quality considered as “safe”.

However, it is not usual to explicitly find performance-based indicators tied to road safety outcomes in PPP contracts. In this research, we focus on indicators that reward the PPP contractor in terms of a certain safety outcome. The advantage of this kind of indicators is that the improvement of road safety is, itself, one of the main social aim for road management. In this respect, monitoring safety explicitly lets the promoter evaluate the achievement of this public benefit directly. Besides, these kind of indicators are quite simple and they are the consequence of the result of many other road performance indicators. This property simplifies PPP contracts, something that is becoming essential.

It must also be taken into account that, in this research, the term “incentive” refers to any kind of economic profit with which the road operator is rewarded in terms of its performance. We have then excluded those PPP contracts where the regulations only impose road safety minimums with penalties if they are not fulfilled but without bonuses if they are exceeded. The importance of highlighting those incentives with bonuses lies in the fact that they encourage the road operator to go “beyond” the expected standards of road safety. These expected standards are usually equal to the minimums mentioned above. In short, it is interesting to enhance those incentives linked to explicit road safety indicators and that include bonuses for the road operator (positive incentives).

Table 1 Breakdown of the introduction of Road Safety Incentives by country

countries with PPP roads with positive incentives based on explicit indicators	countries where PPP roads include other kind of incentives	
Finland	Austria	Greece
Hungary	Belgium	Ireland
Norway	Bulgaria	Italy
Portugal	Czech Republic	Netherlands
Spain	Denmark	Poland
United Kingdom	Germany	Romania

As can be observed in table 1, there are few countries with PPP roads that introduce positive incentives based on explicit road safety indicators. Nevertheless, these countries where this was done, it became a normal practice and the latest PPP contracts continue to introduce and improve these incentives. This happens in Spain, Finland, Hungary, Norway, Portugal and United Kingdom. On the other hand, in France, despite being a country with a large tradition in concession contracts, does not include any safety indicators in their contracts. Italy introduced price-caps tied to road safety indicators in such a way that the concessionaire is allow to set higher tolls if the safety ratios are better. In Ireland, PPP road contracts include some interesting road safety indicators but they do not provide bonuses. In other countries, like Denmark, the Netherlands and Belgium, there are new and sophisticated PPP contracts, but they do not have positive incentives based on explicit road safety indicators.

As a result of this research, we found that countries with a long tradition in PPPs have adopted very different ways in the implementation of safety incentives in their contracts. On the other hand, those countries with less tradition of PPPs but close to each other, have similar contract models. For instance, Germany, Austria and Poland have similar contracts for their PPP roads, but again they do not include positive incentives based on explicit road safety indicators. In all these cases, the exclusion of positive incentive has been intentional. The reasons put forward have more to do with the fact that they have not found a formula to evaluate improvement in road safety rather than with scepticism about their effectiveness.

DESIGN OF INDICATORS

After analyzing the PPP contracts, we discovered that the design of indicators used to evaluate the improvement of road safety is quite heterogeneous. There are differences from the initial accident data to the final formula of the indicator. Specifically, concerning the initial accident data we found the following:

- ✓ Number of injuries
- ✓ Number of fatalities
- ✓ Number of personal injury accidents
- ✓ Number of fatal accidents
- ✓ Combination of number of light accidents, serious accidents and fatal accidents

Most of the PPPs analyzed include only one of these options as initial data to build the indicator, although there are some exceptions. For example, the latest PPP contracts awarded by the Spanish government used both the number of injuries and the number of fatalities.

On the other hand, including the exposure to the risk (expressed by traffic) is a generalized practice. In fact, only the first British shadow toll roads contracts do not introduce traffic, at the time they used absolute number of personal injury accidents as indicator. The rest of the contracts that we analyzed took into account this factor in some way. Most of the time the initial accident data is divided by the annual traffic, usually measured in terms of millions or billions of vehicles-kilometers. E18 road (Muurla–Lohja) in Finland, the M6 road in Hungary, several PPPs in Portugal (the IP-4, for instance) and the latest PPP roads awarded in Spain use this methodology. The advantage of introducing the exposure to the risk (traffic) explicitly is that distortions in road safety results are reduced.

With the same aim, in many other PPP contracts the assessment of the indicator is done by comparing similar roads, in terms of traffic, number of carriageways, type of surroundings, etc. With this methodology it is possible to filter the global evolution of casualties which is notably decreasing in the EU due to many factors, most of them not manageable by the road operator. Some road contracts where the indicator is set in this way are E-18 road (Grimstad – Kristiansand) in Norway, the latest PPP roads awarded in the United Kingdom (for example, A1 & M25) and some PPP roads in Spain (like the M-407 motorway).

Other contracts only assess the evolution of the indicator over the years from what happens on the road itself without comparing the situation to other roads. This is the most common

situation in PPP roads awarded by regional governments in Spain. This is not a good practice for the reason mentioned above: it is necessary to consider a wider framework to filter the global evolution of road safety.

Regarding the period of time considered, PPP contracts that compare the results with other roads always take into account one year. On the other hand, PPP contracts that only analyze the evolution of the indicator in the road itself use one, two or three years. In this respect, considering periods of time between three or five years is better to avoid statistical distortion.

Perhaps the most representative indicator is the one included in the Finish E18 (Muurla-Lohja), the Spanish M-407 and the Portuguese IP-4. This indicator measures the proportional difference between the risk index (number of personal injury accidents related to traffic) of the road and the risk index of similar roads, as expressed in table 2:

Table 2 Road safety indicator in the Finish E18 (Muurla-Lohja), the Spanish M-407 and the Portuguese IP-4

COUNTRY, ROAD and AWARDING YEAR	<ul style="list-style-type: none"> ✓ Finland (E18 Muurla-Lohja); 2005 ✓ Portugal (IP-4); 2008 ✓ Spain (M-407); 2005
ROAD SAFETY INDICATOR	Risk Index (RI) compared to similar roads.
More details	
$RI = \frac{\text{num. of personal injury accidents along one year} \times 10^6}{\text{length of the road} \times AADT \times 365}$ $RI_{sr} = \frac{\sum_r^1 \text{num. of personal injury accidents in the current year in the similar road "r"} \times 10^6}{\sum_r^1 \text{length of the similar road "r"} \times AADT \text{ in the road "r"} \times 365}$ $RSI = \frac{RI_{sr} - RI}{RI_{sr}}$	

The indicator used in Hungary for the M6 road (Érd motorway) is also outstanding. It compares the M6 road in relation to other similar roads. The index assesses four types of

accidents from light to fatal accidents. This makes it possible to evaluate the existence of accidents and their severity. More details about this indicator are given in table 3:

Table 3 Road safety indicator in the Hungarian M6 road (Érd motorway)

COUNTRY, ROAD and AWARDDING YEAR	Hungary (M6 Érd motorway); 2004
ROAD SAFETY INDICATOR	Actual Accident Rate (AAR) compared to similar roads.
More details	
$AAR = \frac{(FA \times 130 + SA \times 70 + LA \times 5 + OA)}{\text{length of the road} \times AADT \times 365} \times 10^6$ <p>FA = number of fatal accidents on the motorway SA = number of serious accidents on the motorway LA = number of light accidents OA = number of other accidents</p> $RSI = AAR_{sr} - AAR$	

In the United Kingdom, recent PPP contracts include a much simpler indicator. It assesses the difference in absolute terms of Personal Injury Accidents (PIA) in the road itself compared to similar roads. The exposure to the risk is implicitly taken into account as traffic is one of the criteria used to define “similar roads”.

From the analysis of all the indicators, we can make the following recommendations:

- ✓ Data used for measuring the indicator must be easily obtained and reliable.
- ✓ Apart from the existence of casualties, their severity must be taken into account in the assessment.

- ✓ The indicator must incorporate the exposure to the risk.
- ✓ The indicator must compare the results with similar roads.
- ✓ It would be appropriate to consider periods longer than a year in the analysis of accidents.
- ✓ The indicator must be simple.

DESIGN OF INCENTIVES

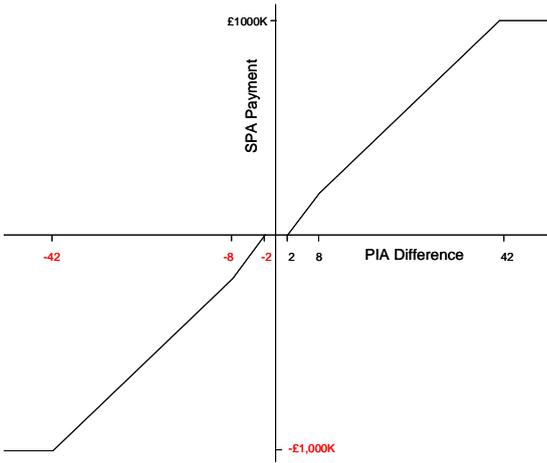
Basically, we have identified two kinds of incentives in the analyzed PPP contracts: incentives related to the deadline of the projects and incentives related to payments. Both of them have an effect on the economics of the road operator.

Table 4 Design of incentives in the latest toll roads awarded by the Spanish Government

COUNTRY, ROAD and AWARDING YEAR	
Spain (AP-46); 2006	
ROAD SAFETY INCENTIVES	
Indicator	Description of the incentive
- Risk Index (RI) and Mortality Index (MI) compared to similar roads.	The contract period is extended if the RI and the MI remain below an accident benchmark for similar roads.
More details	
<p>- The concessionaire is awarded with one more year of concession if, at least, 90% of time during the first 35 years period of the concession, the mortality index and the risk index remain between 90% and 75% of average value of those toll motorways with similar Average Annual Daily Traffic (AADT) (+/- 5,000 vehicles/day).</p> <p>- The concessionaire is awarded with two more years of concession if, at least, 90% of time during the first 35 years of the concession, the mortality index and the risk index remain below 75% of average value of those toll motorways with similar Average Annual Daily Traffic (AADT) (+/- 5,000 vehicles/day).</p>	

In fact, once an incentive has been set, it would be possible to find an equivalent alternative in terms of net present value combining these three variables: fares, expected traffic and concession period. Incentives related to deadline are more common than incentives related to payment increases. Examples of the first one can be found in the latest toll roads awarded by the Spanish Government. In these PPPs, the road operator can be granted one or two additional years of operation of the road if safety indicators remain below an accident benchmark for similar roads, as can be seen in table 4.

Table 5 Design of incentives in the latest PPP roads of the United Kingdom

COUNTRY, ROAD and AWARDDING YEAR	
United Kingdom (A1 & M25); 2003	
ROAD SAFETY INCENTIVES	
Indicator	Description of the incentive
- Personal Injury Accidents (PIA) compared to similar roads.	There are bonuses or penalties up to a maximum of £1M depending on the difference in PIA on the road from the benchmark in proportion to the performance on the Comparator Roads (PIA_{sr}).
More details	
$RSI = PIA_{sr} - PIA$	
Incentive	$\text{if } RSI < 2 \xrightarrow{\text{then}} \text{No Bonus or Penalties}$
	$\text{if } RSI > 42 \begin{cases} RSI > 0 \xrightarrow{\text{then}} \text{Bonus} = \text{£}1,000,000 \\ RSI < 0 \xrightarrow{\text{then}} \text{Penalty} = \text{£}1,000,000 \end{cases}$
	$\text{if } RSI \in [2, 42] \xrightarrow{\text{then}} \text{Bonus or Penalties according to the next liner function:}$
	

As far as incentives related to payments are concerned, they can be divided into two groups: those that link the assessment of the indicator to bonuses and penalties regardless of the traffic level, and those for which bonuses and penalties depend on the traffic volume. PPPs

in the United Kingdom and Hungary belong to the first group. In these contracts there is a linear relationship between the evolution of the road safety indicator and the penalties/bonuses for the road operator, with a maximum figure in both cases. More details are given in table 5. In the rest of the PPPs that were studied, the assessment of the indicator was linked to the annual payment.

The most surprising finding after analysing incentives was that there were huge differences among countries in the penalties and bonuses applied for similar levels of safety indicators. There were also big divergences in the top bonuses or penalties. For instance, in the three PPPs mentioned above as the most representative ones (E18 Muurla-Lohja in Finland, IP-4 in Portugal and M-407 in Spain) that include the same road safety indicator, the bonuses and penalties are substantially different. Specifically, the relationship between the Finnish and Spanish payments is 10/1 respectively and between the Finnish and Portuguese ones is 100/1 as can be seen in table 6. What is more, while the Finnish and Spanish contracts have a top limit for both penalties and bonuses, the Portuguese IP-4 does not have a maximum for neither the bonuses nor the penalties. Nevertheless, the global safety rates are much better in Finland than in Spain or Portugal: for instance, the number of fatalities per billion passenger kilometers in 2007 was 59 in Finland while in Spain it was 108 and in Portugal 128¹).

¹ Source: Transport in figures 2009. EUROSTAT

Table 6 Comparison among road safety incentives

		variation of the annual payment		
		Finland (E18)	Portugal (IP-4)	Spain (M-407)
variation of the RSI	100%	100.0%	-	4.0%
	90%	90.0%	7.2%	4.0%
	80%	80.0%	3.2%	4.0%
	70%	70.0%	1.9%	4.0%
	60%	60.0%	1.2%	4.0%
	50%	50.0%	0.8%	4.0%
	40%	40.0%	0.5%	3.0%
	30%	30.0%	0.3%	2.0%
	20%	20.0%	0.2%	1.0%
	10%	10.0%	0.1%	0.0%
	0%	0.0%	0.0%	0.0%
	-10%	-10.0%	-0.1%	0.0%
	-20%	-20.0%	-0.1%	-6.0%
	-30%	-30.0%	-0.2%	-6.0%
	-40%	-40.0%	-0.2%	-6.0%
	-50%	-50.0%	-0.3%	-6.0%
	-60%	-60.0%	-0.3%	-6.0%
	-70%	-70.0%	-0.3%	-6.0%
	-80%	-80.0%	-0.4%	-6.0%
	-90%	-90.0%	-0.4%	-6.0%
	-100%	-100.0%	-0.4%	-6.0%
-110%	-100.0%	-0.4%	-6.0%	

Moreover, we found that, with the exception of PPPs in the United Kingdom and Finland, safety incentives were not a substantial source of revenues for PPP contractors. The reason is perhaps related to the lack of rigorous studies to justify the introduction of this kind of incentives in the contracts. Without these studies, too much risk could be allocated. In spite of that, what is now happening is that road operators have low incentives for road safety so they are not so willing to invest in road safety improvements.

Despite this, it seems like it is a good feature that PPP contracts include bonuses for road operators to encourage them to improve safety results. The bonuses should be higher than the investment needed to improve safety but lower than the social benefit reached by them.

The most complex thing for the private sector is to estimate the trade-off between the cost of the works and the reduction of safety rates. Social benefits related to safety outcomes have been widely studied and there are even official data in some countries.

CASE STUDY OF SPAIN

Spain has extensive experience in managing and financing motorways through public-private-partnerships (PPPs). Most of the PPPs have been put into effect through concession contracts that have a long tradition in Spanish administrative law. From the beginning, motorway concessions in Spain were awarded to private consortia through competitive bids. This is substantially different from the situation in other European countries such as France and Italy, which directly entrusted toll motorways to public-private companies which were mostly controlled by the government. Most of the motorway concessions awarded in Spain have been toll motorways. However, in the last few years, there was a large increase in the number of other PPP approaches, such as shadow-toll or performance-based contracts.

Three different periods regarding the implementation of motorway concessions in Spain can be identified: from 1967 to 1975, from 1976 to 1995, and from 1996 to the present. Between 1967 and 1975, 2,042 km of toll motorways were granted by the central government of Spain. There are three reasons for the Spanish government's decision to start a toll motorway programme as a means of expanding and improving the Spanish motorway network. First, the economic growth that Spain experienced during these years prompted a large increase in traffic, which suddenly made better motorways a necessity. Second, the state budget in Spain was unable to sustain such a huge investment, so private funding was the only available way to reach this goal.

The results of the implementation of concession contracts in Spain during this period were rather controversial. On the one hand, motorway concessions achieved the goal of providing the country with a modern motorway network at a time when the public budget of Spain was not sufficient to afford such a huge cost. On the other hand, the guarantees made by the government to facilitate concessions' funding over time became very costly for the country (Izquierdo and Vassallo, 2004).

The second stage of motorways concessions is from 1976 to 1995. In this period, no motorway concessions were awarded. There were several reasons for this. First, the two petroleum crises in the 1970s destabilized the Spanish economy. Second, after Franco's death, the political atmosphere in Spain was uncertain. Third, and most important, the Socialist government, which took office in 1982 and remained until 1996, was politically opposed to promoting private concessions as a means to finance motorways. Instead, the

socialist government opted for modernizing the Spanish road network by widening and upgrading the most important roads, turning them into dual-roadway fast lanes with quality standards set well below those for toll motorways. This new programme was completely funded by the public sector.

The third stage began in 1996 and continues into the present. In 1996, the conservative Popular Party took office in Spain. The need to contain Spain's public deficit was the most difficult challenge facing the new government. This was the main reason why the new government decided to implement once again the policy of offering concessions so as to encourage the participation of the private sector in financing new transportation infrastructure. From 1996 to now, 1,003 kilometers of new toll motorways concessions have been awarded by the central government of Spain through this approach.

Until recently, the motorway PPPs implemented by the central government of Spain had always been what are called *greenfield* tolled motorways. However, a few years ago the central government started implementing concessions for the upgrading, refurbishment, maintaining, and operating existing infrastructure (*brownfield projects*) through an approach that combined both shadow toll and performance-based payments. The objective of those contracts was to increase the design standards of the first expressways (*autovías*) built by the Socialist government in the early 1980s and, at the same time, to enhance the quality of their maintenance and operation during the concession period.

The term "*autovías*" was used in Spain in the early years of 80s for identifying any free motorway with physically separated lanes in each direction,. The first *autovías* in Spain were built by duplicating lanes out of single carriageways. The design standards of these motorways (known as first generation *autovías*) had design standards well below those of the toll motorways.

Since 2000 now, the quality standards in the construction of *autovías* improved notably to make comparable with toll motorways. These are called second generation *autovías*. At the time, the main difference between toll motorways and *autovías* is that the legislation prohibits mopeds, tractors and bicycles from entering toll motorways. The first generation *autovías* and second generation *autovías* were built, funded and managed by the Spanish government.

Another novelty of the period since 1996 is that not only the Spanish central government, but also the regional and even the local governments have started using the concession approach to implement both toll and shadow-toll motorways. In the late 1980s an important devolution process took place, with the intent of transferring part of the former network of the central government to the regional governments. In addition to that, the regional

governments were given greater powers to manage and finance their own networks. This is the reason why many regional governments passed specific legislation intending to implement motorway concessions. From 1996 up to now, the regional governments of Spain (called *Comunidades Autónomas*) have in total awarded 1,246 km of shadow toll motorways plus 416 km of toll motorways, which means a larger amount of kilometers than the central government awarded in the same period.

For our analysis, it is necessary to explain the types of road operations in Spain, which are included in this study:

- ✓ First-generation *autovías*.
- ✓ Second generation *autovías*.
- ✓ Toll motorways.
- ✓ Shadow-toll motorways.

Toll motorways in Spain always have a free alternative road. This is the reason why the percentage of heavy good vehicles on toll motorways is much lower than the others types of road operation analyzed in this study.

Apart from road operation, we considered the introduction of incentives in toll and shadow-toll concessions contracts in Spain. As previously explained, Spain begun introducing performance-based indicators linked to bonuses or penalties in toll and shadow toll motorways. These mechanisms are based on indicators related to technical, environmental and safety factors. None of the public motorways (*autovías*) has economic incentives to improve road safety though the government is committed to building and maintaining the *autovías* with socially expected quality standards.

DATA DESCRIPTION

The models that we calibrated in this paper cover only the year 2006. We chose this year because it is the most recent year where we practically have a complete database. In 2006, there were 13,872 km of high-capacity motorways (Annual Report of the Spanish Ministry of Works, 2006).

The data used for our empirical model came from two different sources: police-reported accident data supplied by the Ministry of Internal Affairs (Ministerio del Interior) and traffic data supplied by the Ministry of Public Works (Ministerio de Fomento). Using these databases we built our final database combining both accident data and traffic data. The population for the models were made up of road stretches of the Spanish high-capacity

network both PPP motorways (toll motorways and shadow toll) and public motorways (*autovías*). The average length of the road stretches is 7km.

We selected exogenous variables that may potentially influence safety and do not depend on the concessionaire's ability to manage the road. These are: (1) Average annual daily traffic (AADT), (2) Percentage of heavy goods vehicles (%HGV), (3) Number of intersections for each stretch (INT), (4) Number of lanes for each stretch (LANES). We also selected two variables that may explain any relation between PPPs and accidents: (5) Road operation (RO) and (6) Incentives (INC). Furthermore, in order to fit the model we considered the vehicle exposure (vk).

Data for AADT, %HGV and vk in stretches was available from the Ministry of Public Works (Traffic Map, 2006). Traffic flow is counted as the number of vehicles through a fixed section in both directions, portable counting instrument and permanent inductive loop were used to count the number of vehicles. The number of intersections for each stretch (INT) was obtained from the Geographic Information Science (GIS), the analyses was performed using ArcGis 9.2. The GIS application was used as a tool to integrate of the information in two databases by a common characteristic. The first database included the alphanumeric information about intersections and the second one included geographical information in a digital map of toll motorways and dual carriageways in Spain. Each stretch of the sample was analysed using the GIS application to count the number of intersections. The number of lanes for each stretch (LANES) was calculated by using the number of lanes and the length of the stretches. NL is the weighted mean by length.

Data for Road operation (RO) was obtained from the Traffic map 2006 (Ministry of Public Works) and from a research done by Sánchez et al (2006). RO can be second generation *autovías* (DC), first generation *autovías* (1DC), toll motorways (TM) or shadow toll (ST). TM and ST are PPPs, DC and 1DC are public motorways.

To know which segments had road safety incentives (INC) we analyzed each concession contract in force in 2006. The first Spanish concession contract awarded with implementation of road safety incentives was in 2002. We analyzed all of the contracts from 2002 to 2006.

The vehicle exposure (vk) was measured in millions of vehicle-kilometres as $vk_j = 365 I_j AADT_j / 10^6$, where $AADT_j$ and I_j are respectively the average annual daily traffic and length (Km) of road section j obtained from traffic database.

Data for accidents was supplied by the Ministry of Interior (Accidents database, 2006). For this study, the road safety was measured by the number of fatalities (Fatal).

1,109 road segments were extracted out of a total of 6,293 from the 2006 traffic map, after selection criteria based on complete information for traffic flow, infrastructure variables and reported accidents. The study includes PPPs (both toll and shadow-toll motorways) and public motorways (first and second generation *autovías*). The final date base represents 55.70% of the total Spanish high-capacity network.

The total number of segments and the length by road operation are presented in Table 7. In order to fit the models, 1,109 road segments were considered, of which 17.86% are PPPs (TM and ST), with length of 1,546.67 km, that means 20.02% of the length of the network studied.

Table 7 Road segment data

Road operation	Segments		Length (Km)
	Nº	%	
DC	607	54.73	3,996.43
1DC	304	27.41	2,181.19
TM	176	15.88	1,476.07
ST	22	1.98	70.6
Total	1,109	100.00	7724.285

Table 8 summarises the descriptive statistics of accidents by road operation. The median and the mode are zero for the endogenous variable Fatal, therefore, at least 50% of the data was zero for that variable. The 50 and 75 percentiles indicate that between 50% and 75% of the data are zero. However, the 90 percentile indicates that at least in 10% of the stretches, there are 1 or more fatalities in DC, TM and ST.

The standard deviation is high value compared with the measures of central tendency, therefore, the data have variability and dispersion. The coefficient of skewness is very high

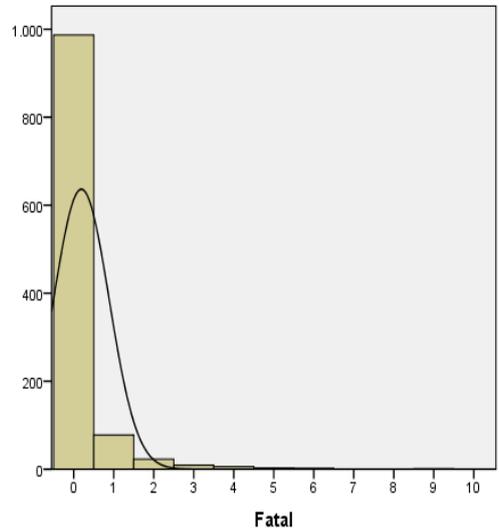
and positive, therefore, the Fatal variable have a right-skewed distribution, which means that the right tail is longer than the left tail.

The histogram of the Fatal variable is presented in Fig. 2. The strong right skew is illustrated by the histogram, therefore, the variable does not have a normal distribution. The histogram indicates a high concentration of the data in the first class, which represents the number of stretches with zero fatalities. This is 88% of the data set.

Table 8 Descriptive statistics of fatalities by road operation. Year 2006.

		Road operation				
		DC	1DC	TM	ST	GLOBAL
Mean		0.21	0.10	0.24	0.41	0.19
Median		0	0	0	0	0
Mode		0	0	0	0	0
S.D.		0.68	0.50	0.91	1.10	0.69
Variance		0.47	0.25	0.82	1.21	0.48
Skewness		4.68	6.40	6.39	3.82	5.69
Range		6	5	9	5	9
Minimum		0	0	0	0	0
Maximum		6	5	9	5	9
Sum		130	30	42	9	211
%Total		61.61%	14.22%	19.90%	4.27%	100%
Percentiles	25	0	0	0	0	0
	50	0	0	0	0	0
	75	0	0	0	0.25	0
	90	1	0	1	1	1

Figure 2 Histogram of Fatalities



The first descriptive statistics for the traffic variables AADT and %HGV indicated the need of the logarithm transformation to expand or contract the distances to extreme values. The measures of central tendency take similar values through logarithm transformation. After transformation, the range values (maximum and minimum) of AADT and %HGV variables were greatly reduced. The standard deviation is very low compared with the mean; therefore, the distribution was further improved. However, the logarithm transformation reduced the skewness coefficient and in some cases it was negative. This means that after transformation, the AADT and %HGV variables had a left-skewed distribution and near normal distribution. The chi square goodness of fit test rejects the null hypothesis that the variables follow a normal distribution.

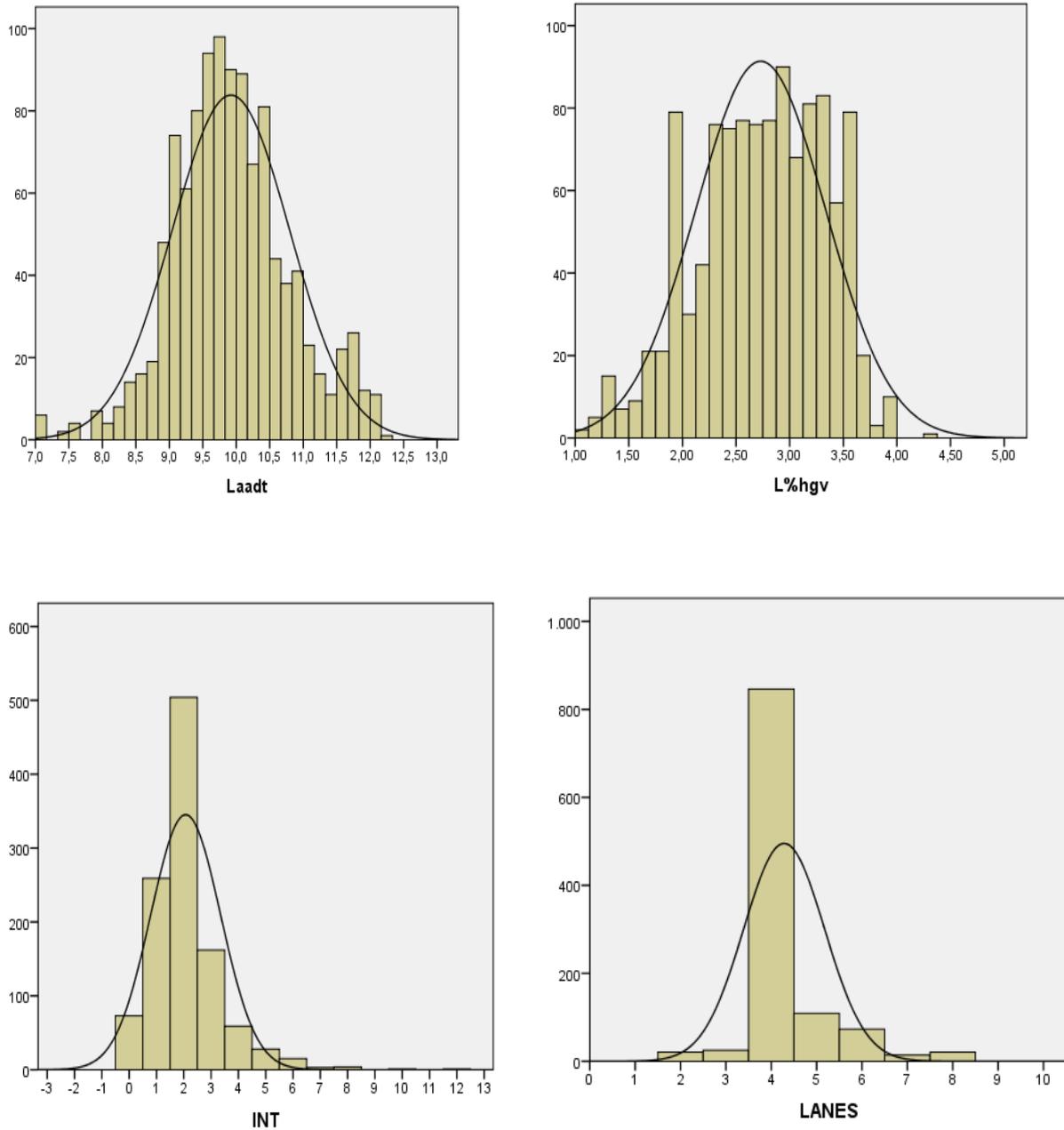
The descriptive statistics after transformation are represented in table 9. Laadt is the logarithm transformation of AADT and L%hgv is the logarithm transformation of %HGV. The descriptive statistics indicate that there are more heavy good vehicles traffic in public motorways (DC and 1DC) than PPPs (TM and ST). On DC, the range and the variance are higher than 1DC, TM and ST, which indicates more heterogeneity in traffic flow. ST has higher homogeneity compared with the other categories.

The mean traffic intensity (Laadt) is higher on 1DC and ST. The high traffic intensity in ST could be explained because the users do not pay tolls and the motorway has a good quality standard.

Table 9 Descriptive statistics of exogenous variables by road operation. Year 2006.

Endogenous variables	Laadt					L%hgv					INT					LANES					
	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	
Road operation	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	DC	1DC	TM	ST	Global	
Mean	9.91	10.19	9.42	10.51	9.92	2.73	3.07	2.21	2.19	2.73	2.08	2.38	1.55	1.68	2.07	4.25	4.30	4.28	5.00	4.28	
Median	9.77	10.06	9.48	10.57	9.86	2.72	3.12	2.28	1.95	2.77	2.00	2.00	2.00	2.00	2.00	4.00	4.00	4.00	5.00	4.00	
Mode	7.15	9.65	9.05	10.43	9.65	2.48	3.54	1.48	2.95	3.54	2.00	2.00	2.00	2.00	2.00	4.00	4.00	4.00	4.00	4.00	
S.D.	0.91	0.72	0.83	0.42	0.88	0.57	0.44	0.56	0.42	0.61	1.21	1.59	0.70	0.65	1.28	0.95	0.73	0.85	1.20	0.89	
Variance	0.83	0.51	0.69	0.18	0.77	0.33	0.19	0.31	0.18	0.37	1.45	2.51	0.49	0.42	1.64	0.91	0.54	0.72	1.43	0.80	
Skewness	0.24	0.69	-0.47	-3.48	0.07	-0.21	-0.94	-0.56	1.12	-0.45	1.05	1.85	-0.32	-0.76	1.67	1.90	2.49	1.09	0.37	1.84	
Std error of skewness	0.10	0.14	0.18	0.49	0.07	0.10	0.14	0.18	0.49	0.07	0.10	0.14	0.18	0.49	0.07	0.10	0.14	0.18	0.49	0.07	
Range	5.12	3.62	3.99	2.12	5.27	3.29	2.43	3.13	1.15	3.92	8.00	12.00	3.00	3.00	12.00	6.00	5.00	6.00	4.00	6.00	
Minimum	7.15	8.54	7.00	8.76	7.00	1.03	1.53	0.40	1.80	0.40	0.00	0.00	0.00	0.00	0.00	2.00	3.00	2.00	3.00	2.00	
Maximum	12.27	12.16	10.99	10.88	12.27	4.32	3.96	3.53	2.95	4.32	8.00	12.00	3.00	3.00	12.00	8.00	8.00	8.00	7.00	8.00	
Percentiles	25	9.25	9.76	9.03	10.43	9.35	2.34	2.87	1.90	1.95	2.32	1.00	2.00	1.00	1.00	1.00	4.00	4.00	4.00	4.00	4.00
	50	9.77	10.06	9.48	10.57	9.86	2.72	3.12	2.28	1.95	2.77	2.00	2.00	2.00	2.00	2.00	4.00	4.00	4.00	5.00	4.00
	75	10.47	10.47	10.00	10.70	10.43	3.20	3.37	2.61	2.75	3.22	3.00	3.00	2.00	2.00	2.00	4.00	4.00	4.00	6.00	4.00

Figure 3 Histograms of exogenous variables: Laadt, L%hgv, INT, LANES.



In order to decide which set of independent variables should be included in the models, correlations between variables were studied to avoid multicollinearity problems. The correlations between variables are presented in Table 10. The range of these correlation coefficients is from -1 to 1 and measure the strength of lineal relationship between variables. For all variables, the p-values are below 0.01, which indicate the statistical importance of correlations different zero for a level of 99% confidence. In practice, the variables with correlation coefficients greater of 0.5 present multicollinearity problems. None of the variables for this study present correlations.

Table 10 Correlations between variables.

	Laadt	L%hgv	INT	LANES	FATAL
Laadt	1	-0.149**	0.109**	0.368**	0.029
L%hgv	-0.149**	1	0.142**	-0.143**	0.002
INT	0.109**	0.142**	1	0.099**	0.086**
LANES	0.368**	-0.143**	0.099**	1	0.077**
FATAL	0.029	0.002	0.086**	0.077**	1

** p < 0,01

METHODOLOGY

Although the ordinary least square regression model (OLS) is widely used in the road safety literature (Hakin et al., 1991; Zlatopher, 1988), some others studies have questioned its suitability (Jovanis and Chang, 1986; Miaou et al., 1992; Miaou and Lum, 1993). This method assumes that the dependent variable is continuous and normally distributed with a constant variance. This technique lacks the distributional property necessary to describe adequately random, discrete and non-negative events such as traffic accidents. The statistics results derived from these OLS models are questionable. One concern in using multiple linear regressions is that the number of traffic accidents may not have a normal distribution but instead follow a Poisson distribution.

The Poisson and Negative Binomial regression models have been widely used to analyze count data where the dependent variable is discrete and defined for non-negative integers corresponding to the number of events occurring in a given interval. However, the Poisson distribution contains certain weaknesses. It assumes that the variance of the dependent variable is equal to its mean but in practice the variance of the traffic accident data tend to be larger than the mean. This extra variation is known as *overdispersion*.

When *overdispersion* is observed the Negative Binomial is preferred. The Negative Binomial regression is an extension of the Poisson distribution.

RESULTS

We have estimated six Poisson regression models. Fatalities were estimated depending on the variables shown below. The general equation in a segment j is:

$$\hat{E}[Y] = \exp(\hat{\beta}_0 + \hat{\beta}_1 \log(AADT) + \hat{\beta}_2 \log(\%HG V) + \hat{\beta}_3 (INT) + \hat{\beta}_4 (LANES) + \alpha_i (RO) + \delta_i (INC) + \log(vk))$$

Where:

AADT is Average annual daily traffic

%HG V is Percentage of heavy goods vehicles

INT is number of intersections for each stretch

LANES is number of lanes for each stretch

RO is Road operation which could be toll motorway, shadow toll, first generation *autovía* and second generation *autovía*.

INC reflects the introduction of road safety incentives in the stretch analysed

vk is the vehicle exposure

Besides those exogenous variables, we included in some models the interaction between traffic and categorical variables.

Table 11 summarizes the six models. Each column refers to a model and every row to an exogenous variables. The empty columns indicate that the variable were not included in the model. We introduced interactions among variables in some models. There is a estimated coefficient for each variable. The significance of coefficients was checked using Wald statistic, which rejects the null hypothesis that the coefficient is zero with a level of 95% confidence. There are different goodness-of-fit statistics for each model, including log-likelihood, Akaike's Information Criterion (AIC) (Akaike, 1974) and the Bayesian Information Criterion (BIC) (Schwarz, 1978).

After analyzing table 11, we could highlight the following results:

1. The *AADT* is the predictor variable most significant of the fatalities in the road segment of this study and its influence depends on the road operation. The percentage of heavy good vehicles is the second most significant predictor variable. Both variables are significant for all models.
2. The models M5 and M6 show that the road operation variable has an influence on the interaction with the *%HG V*s and *AADT*, which indicates that there is a differentiated behavior among toll and shadow motorways, second generation *autovías* and first generation *autovías*.

3. The coefficient signs of the interaction of traffic variables with road operation do not change between models.

4. The INC variable (incentives systems to the concessionaire) was included in all models and there is no change in the sign of the parameter. There are more fatalities on road segments without incentives when are compared with other segments with incentives. INC is significant for all models, so the results indicate that this variable could have an influence on road safety.

5. The LANES variable treated as discrete values (two levels: stretch with more than 4 lanes and stretch with less than 4 lanes) was included in M1 to M4. The results indicate that in stretches with more than 4 lanes seem to have more fatalities than stretches with less than 4 lanes.

6. The INT (intersection) variable presented influence on fatalities. We build 3 different variables types of INT: discrete value with 2 levels (stretch with at least 1 intersection and stretch without intersections), discrete value with 3 levels (stretch with more than 2 intersections, stretch with 2 intersections and stretch with 1 intersection) and as continuous variable which is the number of intersection by stretch. All these variables had an influence. Nevertheless the sign in M3 is different from the M1 and M2.

7. The Pearson's chi-square indicates that the data may be *overdispersed*. When Pearson's chi-square divided by the degrees of freedom is greater than 1, the data may be *overdispersed*, otherwise the data may be *underdispersed*. All models presented Value/df greater than 1, therefore it will be necessary to test the negative binomial as an alternative model. In the next step of this study we will use a negative binomial model, which enables the variance of the dependent variable to differ from its mean.

Table 11 Poisson regression models for fatalitites.

	Measurement level			M1	M2	M3	M4	M5	M6
Intercept				2.457 (5.173)	2.404 (5.102)	1.955 (2.897)	2.439 (5.233)	0.064 (0.003)	0.155 (0.016)
L%hgv	S			-0.182 (1.941)	-0.166 (1.609)	-0.206 (2.575)	-0.196 (2.360)	0.152 (0.882)	0.151 (0.872)
Laadt	S			-0.754 (61.794)	-0.750 (62.141)	-0.760 (62.569)	-0.758 (63.101)	-0.596 (36.608)	-0.603 (36.801)
INC	C	stretch with incentives		-4.658 (0.202)	-5.278 (0.2)	-4.450 (0.190)	-4.570 (0.194)	-0.835 (0.646)	-0.871 (0.700)
		stretch without incentives		0	0	0	0	0	0

	Measurement level			M1	M2	M3	M4	M5	M6
LANES	C	stretch with more than 4 lanes		0.184 (1.061)	0.190 (1.13)	0.169 (0.893)	0.182 (1.049)		
		stretch with less than 4 lanes		0	0	0	0		
INT	C	stretch with more than 2 intersections		-0.13 (0.477)					0.03 (0.023)
		stretch with 2 intersections		-0.107 (0.344)					-0.111 (0.370)
		stretch with 1 intersection		0					0
INT	C	stretch with at least 1 intersection				0.550 (1.468)			
		stretch without intersections				0			
INT	S	number of intersection /km			-0.050 (1.223)				
INC	C	stretch with incentives	L%hgv	1.790 (0.102)	3.298 (0.212)	1.685 (0.094)	1.764 (0.099)		
		stretch without incentives		0	0	0	0		
ROAD OPERATION	C	ST	L%hgv					-2.889 (1.390)	-2.856 (1.360)
		TM					0.81 (3.681)	0.813 (3.721)	
		1DC					-0.353 (1.134)	-0.378 (1.295)	
		DC					0	0	
ROAD OPERATION	C	ST	Laadt					0.667 (2.141)	0.665 (2.130)
		TM					-0.191 (2.838)	-0.188 (2.763)	
		1DC					0.006 (0.004)	0.013 (0.017)	
		DC					0	0	
Lvk	S			1	1	1	1	1	1
Log Likelihood				-568.277	-567.636	-567.651	-568.529	-545.085	-544.678
AIC				1152.553	1151.272	1149.302	1149.058	1110.170	1113.356
BIC				1192.643	1191.362	1184.38	1179.125	1160.282	1173.491
Pearson Chi-Square				2017.631	1985.367	2026.419	2040.073	2265.631	2334.575

Measure level: Scale (S), Categorical (C)

CONCLUSIONS AND FUTURE RESEARCH

The main conclusions of this research are the following:

- ✓ Safety incentives linked to performance based indicators in PPP contracts have not been implemented very often up to now.
- ✓ In order to encourage road operators to improve safety outcomes beyond the expected standards, incentives should include bonuses and not only penalties. However, only few countries in Europe, 6 out of the 18 countries studied, have introduced positive incentives based on explicit indicators in their PPP contracts.
- ✓ In an efficient design of incentives, the bonuses tied to a specific performance level should be lower than the social benefit stemming from that performance level.
- ✓ There are huge differences among countries in the penalties and bonuses applied to similar levels of safety performance.
- ✓ With the exception of the PPPs in the United Kingdom and Finland, safety incentives are not a substantial source of revenues for PPP contractors.

Regarding the specific model for the case of Spain, we found that:

- ✓ Some variables such as the AADT and the percentage of heavy vehicles, which are not manageable by the contractor, are the most significant predictors of fatalities.
- ✓ The implementation of incentives in PPP contractors has a positive influence on road safety in such a way that there are more fatalities on road segments without incentives than in road segments with incentives.

Since we have built an extensive database, with information for some years and other variables, which we have not fully tested yet, such as climatic, we will continue to calibrate models to obtain further useful results.

REFERENCES

Accidents database, 2006. Dirección General de Tráfico, Spain.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Trans. Automat. Control* 19: 716–723.

Annual Report of the Spanish Ministry of Works, 2006.

Debande, O. (2002). “Private financing of transport infrastructure-An assessment of the UK experience”. *Journal of transport Economics and Policy*, Vol. 36, pp. 355-387.

Delgado, C. Vassallo, J.M. and Sánchez, A. (2007) “Aplicación de Indicadores de Calidad en concesiones de carreteras en España”. *Carreteras*, Vol. 151, pp. 53-68.

European Road Safety Action Program 2011-2020 of the European Commission.

European Road Accident Database CARE, 2008

OECD (2008) *Transport Infrastructure Investment: Options for Efficiency*. International Transport Forum: Paris, France.

Hakim, S., Shefer, D., Hakkert, A., Hocherman, I. (1991). “A critical review of macro models for road accidents”. *Accident Analysis and Prevention*, 23 (5), 379–400.

Informe 2006 sobre el sector de autopistas de peaje en España. Delegación del Gobierno en las Sociedades Concesionarias de Autopistas Nacionales de Peaje. Ministerio de Fomento.

Izquierdo, R. and Vassallo, J.M. (2004). *Nuevos sistemas de gestión y financiación de infraestructuras de transporte*. Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid.

Jovanis, P., Chang, H. (1986). “Modeling the relationship of accident to mile travelled”. *Transportation Research Record*, 1068, 42–51.

Miaou, S.P., Lum, H. (1993). “Modeling vehicle accidents and highway geometric design relationships”. *Accident Analysis and Prevention*, 25 (6), 689–709.

Miaou, S.P., Hu, P.S., Wright, T., Rathi, A.K., Davis, S.C. (1992). “Relationship Between Truck Accidents and Highway Geometry Design: A Poisson Regression Approach”. *Transportation Research Record 1376*, TRB, National Research Council, Washington, DC, pp. 10–18.

Sabey B.E. & Staughton, G.G. (1980) “The drinking road user in Great Britain”. Paper presented to the International Conference on Alcohol, Drugs and Traffic Safety, Stockholm, June 1980.

Sánchez, A., Vassallo, J.M., Castroman, A., Delgado, C. (2006). Nuevo modelo de gestión concesional en autovías de primera generación. ETSI Caminos, Canales y Puertos. Universidad Politécnica de Madrid. Ministerio de Fomento.

Schwarz, G., (1978). Estimating the dimension of a model. *The Annals of Statistics* 6, 461-464.

Traffic Map, 2006. Ministerio de Fomento. Dirección General de Carreteras, Madrid, Spain.

Vassallo, J.M. (2007) "Implementation of quality criteria in tendering and regulating infrastructure management contracts". *Journal of Construction Engineering and Management*, Vol. 133 (8), 553-561.

Vassallo, J.M. and Gallego, J. (2005) "Risk-sharing in the New Public Works Concession Law in Spain". *Transportation Research Record*, 1932, pp. 1-8.

Vassallo, J.M. and Pérez de Villar, P. (2010) "Diez años de peaje sombra en España". *Revista de Obras Públicas* (forthcoming).

Zlatopher, T. (1988). "Testing for functional form and autocorrelation in the analysis of motor vehicle deaths". *Q. Rev. Econ. Business* 27 (4), 6–17.