

ANALYSIS OF SAFETY-BASED INCENTIVES IN PUBLIC PRIVATE PARTNERSHIPS. THE CASE OF SPAIN

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ABSTRACT

This paper focuses on the implementation of safety based incentives in Public Private Partnerships (PPPs). The aim of this paper is twofold. First, to evaluate whether PPPs lead to an improvement in road safety, when compared with other infrastructure management systems. Second, is to analyze whether the incentives to improve road safety in PPP contracts in Spain have been effective at improving safety performance. To this end, negative binomial regression models have been applied using information from the Spanish high-capacity network covering years 2007-2009. The results showed that even though road safety is highly influenced by variables that are not manageable by the private concessionaire such as the average annual daily traffic, the implementation of safety incentives in PPPs has a positive influence in the reduction of accidents.

INTRODUCTION

Public Private Partnerships (PPPs) are mostly implemented to circumvent budgetary constraints, and to encourage efficiency and quality in the provision of public infrastructure in order to reach social welfare. 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).

Performance-based approaches have been used as a common compensation for PPPs road projects. In the past few years, PPP contracts have included incentives to encourage bidders to reach the optimum level of service, in such a way that any increase in efficiency will be transferred to the users. These contracts have usually set up indicators linked to bonuses and penalties (Vassallo, 2007; Rangel, 2011).

The incentives given to the contractors should meet the government objectives in the project. The contractor is paid for its performance on specific management activities. These performance based standards often refer to different aspects such as availability, congestion, state of the pavement and safety issues (Rangel, 2011).

A common approach to specifying the quality of service outputs is to develop a matrix of key performance indicators which set the requirements for each service output. The use of “performance measures” or “key performance indicators” (KPIs) are widely used to manage performance in PPP contracts.

The tender process is based on the “best value”. It involves choosing a contractor who, having agreed to comply with the requirements of KPI established in the contract, submits the lowest tender in terms of price. The “best value” approach tries to ensure a high quality at a low cost (Crispino et al., 2008).

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. Therefore, the bidding terms and contracts should comply with two requirements: first, ensure that the most efficient bidder, in terms of price and quality, is awarded the contract; and second, provide incentives to the contractor to render the highest quality level compatible with a reasonable cost.

The aim of this paper is twofold. First, to evaluate whether PPPs lead to an improvement in road safety, when compared with other infrastructure management systems. Second, is to analyze whether the incentives to improve road safety in PPP contracts in Spain have been effective in improving safety performance. We propose a methodology to analyze the effect of safety incentives on accidents in highway PPPs. The results indicate that there are more accidents on road segments without incentives when they are compared with other segments with incentives.

Apart from the introduction, the paper contains four additional sections. In section 2, right after the introduction, we describe the practical experience in the introduction of safety incentives in highway PPPs. In section 3, we describe the characteristics of the highway network in Spain. In section 4 we give a literature review of the models explaining the variables influencing road safety ratios. In section 5 we explain the data sources used for the empirical analysis. In section 6 we develop the methodology and explain the results. In the seventh and last section, we remark the main conclusions.

ANALYSIS OF EXPERIENCES IN THE INTRODUCTION OF ROAD SAFETY INCENTIVES IN EUROPE

Europe is the world region with the greatest tradition of incorporating performance-based incentives in PPPs. There are few countries with PPP roads that introduce positive incentives based on explicit road safety indicators. 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, Slovakia and United Kingdom. In Ireland, PPP road contracts include some 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.

The design of road safety indicators is quite heterogeneous across different countries. There are differences both in the variable adopted to measure the outcome and in the final formula employed. Most of the PPPs include the number of injuries, number of fatalities or a combination of number of light accidents, serious accidents and fatal accidents to build the indicator.

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 with safety incentives took into account this factor in some way. Very often, 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, etc. With this methodology it is possible to control the global evolution of casualties by 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 highway).

Regarding the way of rewarding or penalizing the contractor, we have identified two trends: incentives related to the extension of the deadline of the project, and incentives related to increase of the fee to be paid to the PPP contractor.

CHARACTERISTICS OF HIGHWAYS IN SPAIN

There are two main types of roads in the high capacity highway network in Spain: toll highways (PPPs) and *autovías*. This section presents the characteristics and the differences between these two types of roads.

Spain has extensive experience in managing and financing highways through PPPs. Most of the PPPs have been put into effect through concession contracts that have a long tradition in Spanish administrative law. The first highway concessions awarded in Spain have been toll highways (Izquierdo and Vassallo, 2004). The highway concessions could be toll highways or shadow toll highways. We have not considered shadow toll highways in the analysis because they were recently awarded in Spain.

In the 80s the socialist government opted for modernizing the Spanish road network by widening and upgrading the most important public roads, turning them into dual-roadway fast lanes (*autovías*). The term “*autovías*” was used in Spain in the early 80s for identifying any free highway 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 highways (known as first generation *autovías*) had design standards well below those of the toll highways.

Since 2000, the quality standards in the construction of *autovías* improved notably to make them comparable with toll highways. These are called second generation *autovías*. There is no technical difference between second generation *autovías* and toll highways. The first generation *autovías* and second generation *autovías* were built, funded and managed by the Spanish government. None of the public highways (*autovías*) has economic incentives to improve road safety though the government is committed to building and maintaining the *autovías* with socially expected quality standards.

From 1996 to now, not only the Spanish central government, but also the regional and even the local governments have started using the concession approach to implement toll highways.

In the last few years, Spain began introducing performance-based indicators in toll highways. Toll highway concession contracts include a provision to extend the contract duration up to four years if several performance-based indicators tied to quality aspects like queuing in toll plazas, congestion, state of the pavement, safety, 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, road safety and so on. Regarding safety, the PPP contractor can be granted an extension of the contract if safety indicators remain below an accident benchmark for similar roads. To that propose the government measures in a yearly basis the Risk Index (RI) and Mortality Index (MI) of the highways and compare it with other highways with similar characteristics in terms of alignment and traffic flow.

LITERATURE REVIEW: SAFETY MODELLING AND VARIABLES INFLUENCING ROAD SAFETY

This paper analyzes whether the incentives to improve road safety in PPPs are effective or not. In this section we analyzed many studies to know the effect of variables that influence on accidents and the latest trends in road safety modeling.

Although the ordinary least square regression model (OLS) is applied in the road safety literature (Hakim et al., 1991; Zlatopher, 1988), some other 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. Consequently the statistic 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 relationships using the Poisson distribution have been developed by means of the technique of Generalized Linear Models (GLMs). The Poisson distribution represents a significant advance to describe traffic accident data. However, one of the stated limitations of the Poisson regression model is that the variance of the accident frequency is equal to its mean when in practice the variance of the traffic accident data tends to be larger than the mean. This extra variation is known as overdispersion and if it is present, the estimated coefficients may result biased and inefficient. The overdispersion does not affect the values of the model parameters, but can affect the Wald statistics or likelihood statistics for testing the hypothesis about the parameters. To overcome this problem the more indicated model is the negative binomial (NB) regression.

The literature suggests that the Poisson regression and the NB models possess most of the desirable statistical properties in describing vehicle accident events. The Poisson and NB 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 intervals (Miaou and Lum, 1993; Noland and Oh, 2004; Chang, 2005; Caliendo et al., 2007; Arenas et al., 2009).

Accident rate and accident frequency are the most appropriate dependent variable for predictive models. The relationship between accident rate or accident frequency and traffic flow show a great variation in their results.

Many studies have found the relationship between accident rate and accident frequency and traffic flow. Results showed that accident rate decreases with increasing traffic flow (Martin, 2002; Hauer and Bamfo, 1997); and accident frequency increases with traffic flow (Mohamed et al., 2000; Persaud et al., 2000; Anastasopoulos and Mannering, 2009).

Few authors analyzed the effect that the presence of heavy good vehicles (HGVs) in the traffic flow has on accidents. Hiselius (2004) analyzed the relationship between accident frequency and traffic flow in four different road types according to speed limit and road width in two conditions: homogenous and heterogeneous traffic. The results show that the expected number of accidents increases less than proportionally with the traffic flow, in the homogenous case. For the heterogeneous case, the expected number of accidents decreases with increasing number of trucks.

Other studies have been carried out in recent years to establish relationships between accidents and traffic characteristics and the frequency of intersections (Ivan and O'Mara, 1997), with environmental factors (Chang, 2005; Caliendo et al., 2007; Fridstrøm et al., 1995; Shankar et al., 1995), with geometric infrastructure characteristics (Chang, 2005; Hauer et al., 2004), with number of lanes (Noland and Oh, 2004; Chang, 2005; Milton and Mannering, 1998), with speed limits (Fridstrøm et al., 1995; Ossiander and Cummings, 2002; Wong et al., 2005).

We applied NB regression models to analyze whether PPPs lead to an improvement in road safety when compared with public roads and to know the relationship between safety incentives given to the concessionaires and road safety in Spain, controlling by other variables. This paper focuses on variables related to traffic flow, characteristics of infrastructure and infrastructure management.

This paper updates the research reported by Rangel et al. (2012) which summarizes empirical evidence of the effects of safety incentives (Rangel et al, 2012). This study considers a longer period and consequently random fluctuations are greatly reduced and the recorded number of accidents will more accurately reflect the long term expected number.

The next section describes the data set used and the process of preparing it for modeling.

DATA DESCRIPTION

The models we calibrated in this paper are based on data from 2007, 2008 and 2009. In 2007, there were 13,013.6 km of high-capacity highways, in 2008 there were 13,570.3 km of high-capacity highways and in 2009 there were 14,020.8 km of high-capacity highways (Ministerio de Fomento de España, 2007a, 2008a, 2009a).

The data used for our empirical model came from two different sources: police-reported accident data supplied by the Ministry of Internal Affairs and traffic data supplied by the Ministry of Public Works. Using these databases we built our final database combining both accident data and traffic data.

The sample for the models were made up of interurban road stretches of the Spanish high-capacity network both PPP highways (toll highways) and public highways (*autovías*), with an average length of road stretch being 9km.

We selected a set of exogenous variables that may potentially influence safety and do not depend on the concessionaire's ability to manage the road through a better designs or maintenance. These variables are related to traffic flow such as (1) Average annual daily traffic (AADT) and (2) Percentage of heavy goods vehicles (%HGV), characteristics of infrastructure such as (3) Number of lanes (LANES) and (4) Length of the road stretch (LENGTH). Besides, we selected variables that may explain any relation between PPPs and accidents, (5) Road operation (RO), which reflects the way the highway is managed (public or private) and (6) Incentives (INC), which evaluates whether the private contractors have incentives or not to improve safety if the highways are managed by them.

Data for AADT, %HGV and length of the stretches was available from the Ministry of Public Works (Ministerio de Fomento de España, 2007b, 2008b, 2009b). 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. %HGV was calculated from HGV and AADT, and LANES was calculated using the number of lanes and the length of each stretch. LANES is the mean weighted by length.

We consider the length as the exposure variable. The longer the length of the road stretch, the more likely accidents would occur on these sections.

Data for Road operation (RO), introduced in the model as a categorical variable, was obtained from the Traffic map 2007 - 2009 (Ministry of Public Works) (Ministerio de Fomento de España, 2007b, 2008b, 2009b) and from a research done by Sánchez et al. (2006). This variable takes a different value if the highway stretch is located in a toll highway (TH) concession, a first generation *autovía* (1AV), or a second generation *autovía* (AV). TH are PPPs, while AV and 1AV are public highways.

To know which segments had road safety incentives (INC) we analyzed each concession contract in force in 2007, 2008 and 2009. The first Spanish concession contract awarded with implementation of road safety incentives was in 2002. We analyzed all of the contracts from 2002 to 2009.

Data for accidents was supplied by the Ministry of Internal Affairs (Ministerio del Interior de España, 2007-2009). For this study, the response variable is the accident frequencies.

A total of 3,913 road segments were extracted out of 19,611 from the 2007, 2008 and 2009 traffic map, after selection criteria based on complete information for traffic flow and infrastructure variables. We considered stretches with and without accidents to avoid selection bias. The study includes PPPs (toll highways) and public highways (first and second generation *autovías*). We considered stretches of the Spanish Interurban Road State Network. The final data base represents 77.4% of the total Spanish high-capacity network. The total number of segments (with and without accidents) and the length by road operation are presented in Table 1.

The descriptive statistics of exogenous variables by road operation are presented in Table 2. They indicate that the mean traffic intensity (AADT) is higher on 1AV than AV and TH. The low traffic intensity in TH could be explained because the users have to pay tolls. There is more heavy good vehicles traffic on public highways (AV and 1AV) than PPPs (TH). The range and the standard deviation in AV and 1AV are higher than TH, which indicates more heterogeneity in traffic flow.

TABLE 1. Road segment data.

Road operation	Segments						Length (Km)
	Nº			%			
	with accidents	without accidents	Total	with accidents	without accidents	Total	
AV	902	1,352	2,254	23.05	34.55	57.60	16,138.66
1AV	780	183	963	19.93	4.68	24.61	12,385.67
TH	300	396	696	7.67	10.12	17.79	6,676.61
Total	1,982	1,931	3,913	50.65	49.35	100	35,200.94

The first descriptive statistics for the traffic variables AADT and %HGV and length indicated the need to use the logarithm transformation to expand low values and contract high values. The measures of central tendency take similar values through logarithm transformation. The natural logarithms of the explanatory variables (except for LANES) were used to minimize heteroskedasticity. After transformation, the range values (maximum and minimum) of AADT, %HGV and length variables were greatly reduced. The standard deviation is very low compared with the mean; therefore, the distribution was further improved. However, the chi square goodness of fit test rejects the null hypothesis that the variables follow a normal distribution.

TABLE 2. Descriptive statistics by road operation and total.

Variables	Road operation	Mean	S.D.	Range	Minimum	Maximum
%HGV	AV	15.67	9.16	94.59	1.02	95.61
	1AV	22.75	8.24	74.41	2.12	76.53
	TH	12.56	7.35	51.87	2.36	54.23
	Total	16.86	9.34	94.59	1.02	95.61
AADT	AV	22,100.51	15,751.76	71,810	1,370	73,170
	1AV	24,049.46	12,979.56	65,150	5,117	70,270
	TH	19,906.28	14,575.19	74,730	184	74,910
	Total	21,316.22	14,524.07	74,730	184	74,910
Length	AV	7.16	5.82	47.41	1.00	48.41
	1AV	12.86	11.35	47.41	1.00	48.41
	TH	9.59	7.03	42.15	1.11	43.26
	Total	9.00	8.10	47.41	1.00	48.41
LANES	AV	3.99	0.29	5	2	7
	1AV	4.06	0.27	3	3	6
	TH	4.14	0.56	4	4	8
	Total	4.03	0.35	6	2	8

METHODOLOGY AND MODELING RESULTS

NB regression was applied to determine the relationship between accidents and traffic variables, number of lanes for each stretch, road operation and road safety incentives offered to the concessionaire. In this work the response variable is the accident frequencies.

The general equation in a segment j , road operation ($RO_{ij} = \frac{1}{3}$) being $RO_{3j} = AV$ the reference class, the incentive systems to the concessionaire ($INC_{ij} = \frac{1}{0} = \begin{matrix} yes \\ no \end{matrix}$), and years 2007, 2008 and 2009 ($YEAR_{ij} = \frac{1}{3}$) is:

$$\hat{E}[Y_{ij}] = \exp[\hat{\beta}_0 + \hat{\beta}_1 \log(AADT_{ij}) + \hat{\beta}_2 \log(\%HGV_{ij}) + \hat{\beta}_3 \log(length_{ij}) + \hat{\beta}_4(LANES_{ij}) + \hat{\alpha}_i(RO_{ij}) + \hat{\kappa}_i(INC_{ij}) + \hat{\delta}_i(YEAR_{ij})] \quad (1)$$

Where: $\hat{E}[Y_{ij}]$ is the expected number of accidents; $AADT_{ij}$ is the Average Annual Daily Traffic; $\%HGV_{ij}$ is the Percentage of heavy goods vehicles; $length_{ij}$ is the length of the road section; $LANES_{ij}$ is the number of lanes for each stretch, RO_{ij} is the road operation which could be toll highway (TH), first generation *autovía* (1AV) and second generation *autovía* (AV); INC_{ij} reflects the introduction of road safety incentives in the stretch analyzed; $YEAR_{ij}$ represents the years analyzed in the study.

Table 3 summarizes the NB results. The significance of coefficients was checked using Wald statistic (in bracket), which rejects the null hypothesis that the coefficient is zero with a level of 95% confidence.

In order to select the best accident estimation model, Akaike Information Criterion (AIC) (Akaike, 1974) and the Bayesian Information Criterion (BIC) (Schwarz, 1978) were used. AIC and BIC identify the best approximating model among a class of competing models with different numbers of parameters.

The smaller the value of AIC and BIC, the better the model. Other measures were also evaluated such as deviance, log-likelihood and Pearson chi-square statistics.

To measure the overall goodness-of-fit statistics, the log-likelihood ratio $\rho^2 (= 1 - LL(\beta)/LL(0))$ value of the model (analogous to R-square test in Linear regression models) was used. $LL(\beta)$ is the log-likelihood at converge and $LL(0)$ is the log-likelihood at zero. It is an indication of the additional variation in accident frequency explained by the model to the constant term alone (Fridstrøm et al., 1995).

Table 3 shows that all the variables have the expected sign according to the literature review (with a positive sign indicating an increase in the accident frequency and a negative sign indicating a decrease). Besides, all variables were statistically significant with the exception of %HGV.

Accidents increase with the increase of AADT. The coefficient sign of AADT is positive, suggesting that greater AADT is associated with higher accident frequencies. A similar conclusion was reached for the length. The longer the length of the road section, the more likely accidents would occur on these sections. These results confirm the hypothesis proposed by Mohamed et al. (2000), Persaud et al. (2000) and Anastasopoulos and Mannering (2009).

TABLE 3. Negative binomial regression model for accidents.

Independent Variables	Measurement level		Expected sign	Coefficients (Wald statistics)
Constant				-10.299 (562.309)
Log(AADT)	S		+	1.003 (873.110)
Log(%HGV)	S		+/-	-0.052 (1.699)
Road operation	S	TH	?	-0.225 (14.179)
		1AV	?	0.230 (20.276)
		AV		0
INC	C	stretch with incentives	?	-0.321 (4.255)
		stretch without incentives		0
YEAR	C	2009	?	-0.252 (28.216)
		2008	?	-0.465 (84.880)
		2007		0
Log(length)	S		+	0.746 (894.888)
LANES	S		+	0.094 (3.062)
Summary statistics				
AIC				16,427.776
BIC				16,490.505
Deviance (D^p)				4,222.599
Pearson Chi-Square (X^2)				4,977.103
Log-likelihood at converge				-8,203.888
Log-likelihood at zero				-9,399.909
$\rho^2 (= 1 - LL(\beta)/LL(0))$				0.13
Overdispersion				1.081

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

The expected number of accidents decreases with increasing percentage of trucks. The coefficient sign of %HGV is negative. This could be related to the reduction of speed that heavy vehicles impose on light vehicles in the traffic flow. This result is in line with Hiselius (2004).

RO indicates that there is a different behavior among toll highways, second generation *autovías* and first generation *autovías*. Toll highways (TH) showed the expected negative sign suggesting that there are fewer accidents in toll highways compared with AV. Besides, results indicate that there are more accidents in 1AV compared with AV. In other words, toll highways managed and operated by the private sector turn out to be safer than free highways managed and operated by the public sector. Toll highways have better road maintenance than public highways.

The INC variable showed the expected negative sign, suggesting that establishing incentives in the contracts is associated with lower accidents. There are more accidents on highway segments without incentives than on highway segments with incentives.

The results show that road safety is improving over the years; in 2007 there were more accidents than 2008 and 2009.

A larger number of LANES is associated with more accidents. The reason for this is that in highways with more lanes the interactions between drivers is greater so the probability of crashing increases. This result is in line with the findings by Noland and Oh (2004), Chang (2005) and Milton and Mannering (1998), and that the accident risk increases with the number of lanes.

CONCLUSIONS

This paper presents a model of accident frequency to know whether PPPs lead to an improvement in road safety when compared with public roads and to know whether the implementation of road safety incentives in PPPs is an effective measure to improve safety ratios in Spain.

The main conclusions from this research are that PPP highways managed and operated by the private sector are safer than free highways managed and operated by the public sector; and road safety incentives given to the concessionaires have a positive influence on accidents. There are more accidents on public highways than PPP highways and there are more accidents on PPP road segments without incentives than in PPP road segments with incentives.

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 accidents. Even if the regulations offered limited opportunities to manage road safety, the contractor should still be allowed to find ways of including any safety measures not foreseen by the regulations.

An important direction for future research would be to analyze the size of the economic incentive set up in the PPP contract on the ultimate improvement of safety ratios.

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