Charging for use of infrastructure by road freight: European experience

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1. Introduction

The European Commission has a clear policy of implementing marginal social cost pricing across the modes, although progress in achieving that is slow. In the next section, this paper will review the current state of European legislation. It will then review the large amount of research the European Commission has sponsored into measuring marginal social cost, with particular reference to road freight. It will then examine the experience of kilometre based charges for road freight vehicles (concentrating on the examples of Switzerland, Germany and Austria). Finally it will consider the issue of regulation, and what may be learned from the experience of the rail sector, with particular reference to recent proposals in Britain, before reaching its conclusions. The paper rests heavily on Link et al (2014) and Nash et al (2008).

2. Legislation

For many years the European Commission has sought to implement a policy of marginal social cost pricing on all modes of transport in order to give appropriate incentives regarding vehicle type and use, to achieve fair competition across the modes, and to help finance infrastructure. Progress has been slow. With respect to road goods transport, there has been particular concern in that the variety of systems and levels of charging have distorted competition between road hauliers based in different EU countries.

Traditionally there have been two approaches to charging for the use of roads in Europe. The first has been through annual licence duty and fuel tax. The second has been to add to these specific tolls on certain roads. Needless to say, countries which adopted the latter generally had lower levels of annual licence duty and fuel tax than the former. The result is that when vehicles from such countries operate in countries with higher levels of taxes, they are at a considerable advantage, especially if they are able to buy much of their fuel before they come. Conversely, vehicles from high tax countries operating overseas are at a disadvantage as they have to pay tolls on top of the high taxes in their own country.

The origin of the Eurovignette system was in an attempt to overcome this problem. Initially Germany, but following that also the Benelux countries, Sweden and Denmark, introduced a system whereby all vehicles using the motorway system of the country concerned had to buy a supplementary licence known as a vignette. This was valid for a given period of time – a day, month or year. The original Eurovignette Directive was designed to regulate this charge to ensure that it was not used to discriminate between vehicles of different countries or to exploit monopoly power.

However, a charge based purely on time clearly does not reflect the costs imposed by use of the road system at all well, so successive revisions of the Eurovignette Directive have made provision for a charge based on distance and differentiated by the type of vehicle (e.g. gross weight, axleweight, pollution class), the type of road it was running on (e.g. pavement thickness, urban or rural) and the time of day (important for noise and congestion). The latest revision is Directive 2011/76/EU. This permits charging for marginal maintenance and renewals costs, noise, air pollution, and differentiating charges according to levels of congestion, although the overall revenue raised from this charge must not exceed the costs of providing the road system as a whole (to avoid giving an incentive to countries with a high level of transit traffic to limit capacity and force up price).

In the case of rail, going back to Directive 91/440 in 1991, the European Commission has had a policy of separating rail infrastructure and operations and allowing new entrants to compete in operating train services. The current position is that any licensed train operator may run rail freight services anywhere in the European Union. This creates a set of issues very similar to those involved in charging for use of the road infrastructure by road freight vehicles. The current position regarding rail track access charges is in the course of being revised under the recast of the first rail package of measures, and will in due course be set out in detailed guidance under an implementation act. But broadly it requires charges to be based on the 'direct cost' of the train concerned, which is interpreted to mean marginal maintenance and renewals costs. Charges for externalities such as noise and air pollution are permitted, but may not increase the absolute level of charges unless such charges are also levied on other modes. Reservation charges are permitted, as are congestion charges and non discriminatory mark-ups where needed for financial reasons.

3. Estimation of marginal social cost

3.1 Introduction

In order to implement this policy, the European Commission has commissioned numerous research projects, the results of which are brought together in the IMPACT handbook on estimating external transport costs (see INFRAS et al., 2008). However, this handbook focuses on external costs and excludes the marginal costs of operating, maintaining and renewing transport infrastructure.

This section will review research on measuring all the main elements of marginal social cost. It draws heavily on Link et al (2014).

3. 2 Infrastructure cost

The marginal infrastructure cost comprises the additional cost of maintaining, renewing and operating infrastructure when an additional vehicle or train runs over it. Construction and enhancement costs are excluded, since the Commission follows a short run marginal social cost pricing approach.

Traditionally the marginal cost of infrastructure operation, maintenance and renewal has been estimated by the use of cost allocation methods, sometimes informed by engineering formulae. Thus for instance the costs of maintaining and renewing roads has been estimated by taking each cost category (such as pavement renewal), defining cost drivers (such as vehicle km, or standard axle kilometres – a measure which combines the number and weight of the axles) based on judgement, and then allocating this cost to individual vehicles based on these cost drivers. The problems with this approach are that it rests heavily on the judgement of those involved and that it makes no allowance for the possibility of economies or diseconomies of scale in the activity concerned.

More recently the use of econometric methods to estimate the relationship between transport infrastructure maintenance, renewals and operations expenditure and traffic volume based on a neoclassical cost function approach has allowed more objective measures of marginal cost to be developed (for a general discussion see Link and Nilsson, 2005). Results from some recent studies are given in Table 1. However, the econometric approach cannot generally be used to determine the relative impact of individual vehicle types, due to frequently reported problems with multicollinearity between the traffic variables. Allocation of marginal costs to vehicle types has therefore typically to be based on engineering studies of relative wear.

Apart from the cost function approach, the duration approach has been developed and tested in some studies (see for example Lindberg, 2002). This approach refers exclusively to renewal costs and is based on the assumption that the length of interval between two renewals of the road surface depends on the number of standard axles which used the road section. The change in the lifetime of road surfaces as traffic changes is the basis for calculating the marginal renewal cost, subject to the assumption that renewals are conducted according to renewal needs.

Both econometric cost function studies and studies using the duration approach were undertaken within the EU funded projects UNITE, GRACE and CATRIN for road and rail infrastructure. The most important outcomes of these studies for generalization are the estimates for the elasticity of these cost elements with respect to measures of output. This elasticity shows the ratio of marginal costs to average costs, and means that once average cost is known the marginal cost can be estimated. It appears that most studies found that the elasticity for road infrastructure cost decreases as the measure changes from renewal to maintenance and to operation (see table 1). The average elasticity for renewal cost is between 0.5 and 0.8 and for maintenance cost between 0.4 and 0.7 while the elasticity for operations cost appears to be more or less zero. Thus, ignoring externalities efficient prices for road transport would be somewhat below average costs.

Table 1: Estimated cost elasticities for road infrastructure costs

Study	Country	Type of network	Type of study	Cost elasticity (MC/AC)
Renewals				
Lindberg (2002)	Sweden	All roads	Duration approach	**0.1...0.8**
Link (2006)	Germany	Motorways	Econometric cost function study	**0.87**
Bak et al. (2006)	Poland	National roads	Econometric cost function study	**0.57**
Renewals and Maintenance				
Schreyer et al (2002)	Switzerland	Motorways and main roads	Econometric cost function study	**0.71**
Sedlacek and Herry. (2002)	Austria	Motorways	Econometric cost function study	**1.046**
Haraldsson (2006)	Sweden		Econometric cost function study	**0.58**
Bak et al. (2006)	Poland	National roads	Econometric cost function study	**0.48**
Maintenance				
Schreyer et al (2002)	Switzerland	Motorways and main roads	Econometric cost function study	**0.69**
Bak et al. (2006)	Poland	National roads	Econometric cost function study	**0.12**
Jonsson and Haraldsson (2008)	Sweden	All roads	Econometric cost function study	**0.39**
Link (2009)	Germany	Motorways	Econometric cost function study	**0.47**
Operations				
Haraldsson (2006)	Sweden	Paved roads	Econometric cost function study	**(0.03)**
Haraldsson (2006)	Sweden	Gravel roads	Econometric cost function study	**(-0.09)**
Source: Link et al (2014)				

3.3 Road congestion

The charging-relevant measure of congestion costs is the marginal external congestion costs, i.e.. the difference between social marginal cost and private marginal cost. By far the major part of congestion costs is the marginal time cost. Further costs comprise additional fuel costs and the corresponding environmental costs; due to their lesser quantitative importance these costs are often ignored or considered in a general way by just adding a mark-up to the time cost estimate[1]. The marginal external time cost may be measured as the difference in journey time caused by one extra vehicle on the road multiplied by an estimate of the value those concerned place on their travel time.

One major methodological issue to be taken into account here is the need to estimate the marginal external congestion costs after introducing a congestion charge, that is by taking into account responses of road users. This implies that an optimal congestion charge has to be determined at the optimal traffic level and will be lower than the current marginal external congestion costs due to adjustments of traffic demand. Estimating the marginal external congestion cost as an optimal toll also implies that the elasticity of demand has to be known.

A second methodological issue concerns the approach used to measure how congestion costs rise with an increase in traffic. There are several approaches for estimating the change in journey time, ranging from speed-flow relationships, aggregate approximations such as area speed-flow curves, queuing models and simulation models. For individual inter urban roads with no close substitutes, a simple relationship between speed and the volume of traffic on the road may be applied. Area-wide speed-flow models were used in Proost and van Dender (1999) and in Prud'homme and Kopp (2006). But wherever there are substitute roads, as there invariably are in urban areas, this will not explicitly consider the costs created by some traffic diverting to other routes. Thus a network model is needed, such as the SATURN model (Van Vliet, 1982) which was used in GRACE and UNITE.

Evidence on values of time in European countries is given in Bickel et al (2006). The value of time used in freight traffic in Europe is typically just the salary of the driver, plus overhead costs of employing labour, plus standing costs of the vehicle. Although research has been done into the value of time savings for the freight itself, according to the commodity carried, for most European road traffic the amount of time saved is insufficient for this to be a major consideration.

3.4 Accidents

Accident costs comprise the following major components:

- Direct economic costs which can be observed as current and/or future expenditure. This includes medical treatment and rehabilitation costs, legal and administrative costs, emergency services and property damage costs.
- Indirect costs which include the lost production capacity to the economy caused by premature death or reduced working capability due to the accident.
- The value of safety per se. This is the risk value (Value of Statistical Life - VSL) which reflects the willingness-to-pay of people to reduce the probability of premature death due to an accident. This value is viewed as a proxy for pain, suffering and grief caused by an accident.

[1] Typically, a mark-up of around 10% is used (see INFRAS et al., 2008).

The magnitude of marginal external accident costs depends on the accident risk, the risk elasticity, the underlying assumptions on the external element of social marginal accident costs and on the valuation methods, in particular on the estimation of the VSL. To start with the distinction between external and internal parts of accident costs, two issues have to be resolved. The first concerns risk anticipation. Under the assumption of rational behaviour and complete information users will take into account the risk of having an accident in their transport decisions, and all the costs they would experience in this event. This would include their own pain and suffering, damage to their own property and loss of income through time off work. The second issue is the allocation of insurance premiums. Arguably internal marginal cost would also include those costs users meet through insurance, on the basis that insurance payments adjust to accident risk. What it would not include is those costs borne by the state, including medical, ambulance and policing costs, and social security payments for loss of earnings. Nor would it include costs imposed on other road users and their insurers, for instance by increased accident risk if the risk elasticity is greater than one.

Even though there is a large volume of studies on the estimation of the VSL, the estimation approaches (usually contingent valuation methods) still face a great deal of uncertainty. Available estimates show a considerable variation around the world, ranging from 200000 US$ to 30 million US$ (see de Blaeij, 2003). A detailed discussion of the problems can be found in Lindberg (2006). Table 2 shows values for both the VSL and for the direct and indirect economic costs recommended by Bickel et al. (2006).

It should be noted that the problems related to the concept of the contingent valuation method which trades-off money versus risk without considering a particular travel situation, has led to the use of stated choice techniques in estimating the VSL (see for example Rizzi and Ortuzar, 2006).

Finally, there is still no consensus on the risk elasticity. An increase in the number of vehicles increases the number of possible interactions according to the square of the volume. This would lead to the expectation that the risk should increase with traffic volume. However, many studies find decreasing risk with increasing traffic volume. This could be a problem associated either with the studies or behaviour effects. If we do not control for infrastructure quality, we may find that roads with higher expected traffic volume are designed with a higher traffic safety standard. In addition, road users may react to a perceived increased risk by driving more carefully and slowly. This is an unobserved cost component that would increase the cost. In the absence of evidence on these effects, current research seems to be pointing to relatively low external accident costs.

Table 2: Recommended values from HEATCO for the Value of Life (VSL) and for direct and indirect economic costs of accidents (Euro 2002, factor prices)

	Value of safety per se*			Direct and indirect economic costs		
Country	Fatality **	Severe injury	Slight injury	Fatality	Severe injury	Slight injury
Austria	1600	208	16	160	32.3	3.0
Belgium	1490	194	14.9	149	55.0	1.1
Cyprus	640	83	6.4	64	9.9	0.4
Czech Republic	450	59	4.5	45	8.1	0.3
Denmark	2000	260	20.0	200	12.3	1.3
Estonia	320000	41	3.2	32	5.5	0.2
Finland	1580	205	15.8	158	25.6	1.5
France	1470	191	14.7	147	34.8	2.3
Germany	1510	196	15.1	151	33.4	3.5
Greece	760	99	7.6	76	10.5	0.8
Hungary	400	52	4.0	40	7.0	0.3
Ireland	1940	252	19.4	194	18.1	1.3
Italy	1300	169	13.0	130	14.7	1.1
Latvia	250	32	2.5	25	4.7	0.2
Lithuania	250	33	2.5	25	5.0	0.2
Luxembourg	2120	276	21.2	212	87.7	0.7
Malta	910	119	9.1	91	8.8	0.4
Netherlands	1620	211	16.2	162	25.6	2.8
Norway	2630	342	26.3	263	64.0	2.8
Poland	310	41	3.1	31	5.5	0.2
Portugal	730	95	7.3	73	12.4	0.1
Slovakia	280	36	2.8	28	6.1	0.2
Slovenia	690	90	6.9	69	9.0	0.4
Spain	1020	132	10.2	102	6.9	0.3
Sweden	1700	220	17.0	170	53.3	2.7
Switzerland	2340	305	23.4	234	48.8	3.7
United Kingdom	1650	215	16.5	165	20.1	2.1

* Value of safety per se based on UNITE (Nellthorp et al., 2001): fatality 1.5 million Euro (market price 1998 – 1.25 million Euro factor costs 2002); severe/slight injury 0.13/0.01 of fatality; direct and indirect economic costs; fatality 0.1 of value of safety per se; severe and slight injury based on European Commission 1994. ** Benefit transfer for EU value of 1.25 million Euro based on GDP per capita ratios (income elasticity of 1.0).
Source: Bickel et al. (2006).

3.5 Noise

Noise costs consist of two categories: First, the cost for annoyance reflecting the disturbance which individuals experience when exposed to traffic noise. Second, health impacts, which are related to long-term exposure to noise and lead to stress related health effects such as hypertension and myocardial infarction. The common assumption is that these two effects are independent. There are several peculiarities which make the estimation of noise costs, in particular marginal noise costs, a challenging task. First, the perception of sound follows a logarithmic scale which implies non-linearities of impacts and the corresponding costs due to a change in noise levels. Second, the background level of noise is important: The same change in noise levels leads in a quiet neighborhood to higher marginal costs than in a noisy environment.

The state-of-the-art in calculating marginal noise costs is the impact pathway approach (see the projects ExternE, UNITE and NewExt for details) which involves five steps: First, estimating the increase of noise emissions per additional vehicle (in dB(A)) and modeling the reception of sound by considering the spreading, the atmospheric, ground and screening attenuation, the sound reflection and the meteorological conditions. Second, measuring the impacts of the different noise levels due to change in traffic flow on human health and annoyance through dose-response functions. Third, quantifying the number of persons exposed to noise. Fourth, predicting the physical impacts of noise on human health and welfare by applying the dose-response functions to the exposed population, and fifth, valuing these effects in monetary terms.

One of the most important methodological issues within this procedure is the valuation method. While for some effects market prices can be used (for example for medical costs) the most popular approach for valuing nuisance effects of noise is to estimate the willingness to pay for its reduction or to accept compensation for its continuation, either by hedonic pricing or within stated preference (SP) or revealed preference (RP) studies. This involves a number of methodological issues such as the choice of the threshold above which noise is considered as having an impact on annoyance and human health, and the valuation method applied for transferring physical impacts into monetary terms. The WHO recommends a noise threshold of 55 dB(A) above which people feel seriously annoyed. It should be noted that the choice of the threshold is a sensitive decision in estimating noise costs (see for example ECMT 1998 which demonstrates that moving from 50 to 55 dB(A) decreases the average noise costs by 50%).

With regard to the valuation method, the literature is dominated by hedonic pricing studies which use evidence on the relationship between noise nuisance and house prices (see for example Nellthorp et al., 2007). This is because, unlike air pollution, noise has been considered a readily perceived cost mainly in terms of amenity. The major advantage of hedonic pricing studies is that they build upon real market behavior. However, variations in housing prices might also be caused by other negative impacts of traffic and are subject to conditions in the local housing market (see Navrud, 2002) which need to be taken into account properly. However, often there is imperfect knowledge on the attributes of each location implying that this precondition cannot be met. Correlation of the explanatory variables and the difficulties in measuring the intangible influences as well as individuals' perception of them add to these problems (see Wardman et al., 2005). Furthermore, with the hedonic pricing approach only one observation per person can be obtained and the method is subject to problems of self-selectivity. The advantage of SP methods for estimating WTP values is that several characteristics that naturally belong together can be valued simultaneously and aggregation bias can be avoided. The experimental design can ensure a sufficient variation in the attributes guaranteeing more precise estimates and the capability to analyse non-linear effects. Furthermore, SP values are more robust to value transfer (Navrud, 2002). Major problems of SC methods are strategic answering, protest responses and the hypothetical character of the method. Studies based on SC methods for estimating WTP values for noise reduction are less widespread than hedonic pricing studies. Examples include Galilea and Ortuzar (2005), Wardman et al. (2005), Wardman and Bristow (2008) and Arsenio (2002).

3.6 Air pollution

Air pollution costs are caused by the emission of air pollutants such as particulate matters (PM10, PM2.5), Nitrogen oxides (NOx, No2), Sulphur oxide SO2, Ozone O3 and volatile organic compounds VOC. The costs consist of health costs, damages of materials and buildings, crop losses, and damages of the ecosystems (soil, water, biosphere). Health costs are by far the most important cost category.

The standard approach to measuring the costs of air pollution in recent studies is the impact pathway approach as already introduced in the previous section, which models in turn the volume of emissions, their dispersion in the atmosphere, their deposition (for instance on crops and buildings and in people's lungs) and the physical damage they do. This is then valued in money terms. The most decisive parameters and assumptions in the estimation process refer to the emission factors (by technology) for all types of vehicles, the dose-response functions used for quantifying the physical impacts and the VSL used to value the risk of death or ill health due to air pollution. It should be noted that the choice of epidemiological studies to derive dose-response functions impacts considerably on the magnitude of health costs even for air pollution studies which apply the same dispersion model. Bickel and Friedrich (2005) give dose-response functions for different types of pollutants. Valuation of health impacts due to air pollution uses willingness to pay to avoid the risk of death or ill health. While earlier studies have used the value of Statistical Life (VSL), more recent studies such as HEATCO and CAFÉ CBA (Holland et al., 2005, Hurley et al. 2005) favour the value of life year lost (VLYL) (for more details see INFRAS et al., 2008). Damage to buildings is valued at market prices by using repair costs; crop losses are valued by estimating the losses of agricultural products at market prices.

3.7 Global warming

Estimating the costs of climate change caused mainly by the emission of greenhouse gases such as carbon dioxide CO_2, nitrous oxide N_2O and methane CH_4 is a complex task due to the global and long-term character and the risk pattern involved. Impacts of climate change include sea level rise, energy use impacts, agricultural impacts, water supply impacts, health impacts, impacts on ecosystems and biodiversity, extreme weather events and catastrophic events or major climate discontinuities.

The common approach in estimating global warming costs consists of multiplying the amount of CO_2 equivalents emitted by a cost factor whereby the CO_2 equivalent of a greenhouse gas is derived by multiplying the amount of the gas by the associated global warming potential (GWP)[2]. There are two main approaches for the valuation of climate change impacts. First, several studies such as Pearce (2003), Wahba and Hope (2006), Parry et al. (2007), Lemp and Kockelmann (2008) and Delucci and McCubbin (2010) have used the damage cost approach which is based on an assessment and monetary valuation of physical impacts of climate change. The available estimates vary by orders of magnitude, amongst other factors due to the use of different social discount rates and different equity weighing (relationship between changes in consumption and changes in welfare). A second approach is the avoidance/abatement cost approach. To the extent that countries have signed up to binding targets on greenhouse gases, extra greenhouse gases from transport imply cuts elsewhere. In this case, abatement costs can be used as cost factors (Watkiss, 2005).

A European abatement cost of €20 per tonne of CO_2 represents a central estimate of the range of values for meeting the Kyoto targets in 2010 in the EU based on estimates by Capros and Mantzos (2000). They report a value of €5 per tonne of CO_2 avoided for reaching the Kyoto targets for the EU, assuming a full trade flexibility scheme involving all regions of the world. For the case that no trading of CO_2 emissions with countries outside the EU is permitted, they calculate a value of €38 per tonne of CO_2 avoided. It is assumed that measures for a reduction in CO_2 emissions are taken in a cost effective way. This implies that reduction targets are not set per sector, but that the cheapest measures are implemented, no matter in which sector. Recent work has confirmed the assumption that emissions in future years will have greater total impacts than emissions today (Stern 2006). On the other hand, studies such as IVM (2006) have shown that ex-ante assessments of future avoidance costs tend to overestimate costs.

For application in GRACE which is the basis of our results presented in section 3 we used a range of €14 to €51 (with a central value of €22 per tonne of CO_2- equivalent emission in the period 2000 to 2009). These shadow prices were derived from Watkiss et al. (2005), by converting the values expressed in £ at 2000 prices into € at 2002 prices (factor prices). It should be noted that the European Commission has now accepted a need to meet much more stringent emissions targets for greenhouse gases; these are a 20% reduction in CO_2 by 2020 with the possibility of extending it to 30% if other countries follow suit (Commission of the European Communities, 2007). In addition, the Commission has accepted that for developed countries a 60-80% reduction will be needed between 1990 and 2050. These targets both imply higher shadow prices of greenhouse gases now, and a strong upward trend in those shadow prices over time. Also national reduction policies meanwhile assume higher shadow prices. For example, the British government assumes that the shadow price of CO_2 will go from £18.6 in 2000 to £59.6 in 2050, for a policy aiming at a 60% cut by 2050 (see DEFRA, 2007). This seems to support sensitivity testing of a factor of 4. Thus in what follows we will test the sensitivity of our conclusions to shadow prices for greenhouse gases between twice and four times those we assumed.

[2] The GWP for methane is 23, for nitrous oxide 296, for CO2 it is 1.

3.8 A Case Study

An example of the resulting marginal costs for a Euro 2 heavy goods vehicle (Euro 2 refers to the pollution standards of the vehicle and relates to a relatively old goods vehicle well below current standards for new vehicles) is given in Table 3. It will be seen that even for such a vehicle, in typical European conditions wear and tear and congestion dominate marginal social cost.

Table 3 Case study results from GRACE: Marginal costs of road transport at the Milan-Rotterdam corridor – HGV Diesel Euro II (€ vkm)

	Milan-Chiasso			**Chiasso-Basel**		
	Peak	Off-Peak	Night	Peak	Off-Peak	Night
Noise	0.046	0.076	0.230	0.028	0.046	0.138
Congestion	0.724	0.011	0.004	1.001	0.012	0.005
Accident	0.115	0.115	0.115	0.078	0.078	0.078
Air pollution	0.030	0.030	0.030	0.037	0.037	0.037
Climate change	0.021	0.021	0.021	0.021	0.021	0.021
Wear and tear	0.132	0.132	0.132	0.256	0.256	0.256
Total	**1.068**	**0.385**	**0.532**	**1.421**	**0.450**	**0.535**
	Basel-Duisburg			**Duisburg-Rotterdam**		
	Peak	Off-Peak	Night	Peak	Off-Peak	Night
Noise	0.036	0.059	0.178	0.058	0.095	0.287
Congestion	0.657	0.009	0.004	0.660	0.009	0.004
Accident	0.050	0.050	0.050	0.028	0.028	0.028
Air pollution	0.031	0.031	0.031	0.032	0.032	0.032
Climate change	0.021	0.021	0.021	0.021	0.021	0.021
Wear and tear	0.151	0.151	0.151	0.158	0.158	0.158
Total	**0.946**	**0.321**	**0.435**	**0.957**	**0.343**	**0.530**
Notes: Peak Period – 07.00 to 18.00, Off-Peak – 18.00 to 00.00. Night – 00.00 to 07.00. Source: Ricci et al. (2008)..						

4. Pricing in practice

4.1 Introduction

As noted above, the origin of the Eurovignette system was in an attempt to overcome the problem of distorted competition as a result of vehicles from countries with toll roads but low taxes on goods vehicles. Initially Germany, but following that also the Benelux countries, Sweden and Denmark, introduced a system whereby all vehicles using the motorway system of the country concerned had to buy a supplementary licence known as a vignette. This was valid for a given period of time – a day, month or year. The original Eurovignette Directive was designed to regulate this charge to ensure that it was not used to discriminate between vehicles of different countries or to exploit monopoly power.

Although Norway and Sweden used to have kilometre based heavy goods vehicle charges these were abandoned when Sweden joined the European Union and by the 1990s no such charges existed in Europe. Since then, several European countries have introduced kilometre based charges and more are considering it. The first was Switzerland (not an EU member, but with an agreement generally to follow EU transport policy) followed by Austria and Germany. Several other countries have since implemented kilometre charges whilst others are considering it. Britain also proposed a km charge for heavy good vehicles but has since reverted to a simple time based vignette.

4.2 Switzerland

Although not a member of the European Union, Switzerland was the first country to introduce a kilometre based charge for heavy goods vehicles. Of course this was not constrained to follow the Eurovignette Directive. The Swiss Heavy Vehicle Fee (HVF) came into operation on January 1 2001. The charge was levied on the entire Swiss public road network, applying to both Swiss and foreign vehicles alike, weighing over 3.5 tonnes. It coincided with Switzerland giving way to pressure from the European Union to permit heavier goods vehicles, with the weight limit rising from 28 tonnes first to 34 and then 40.

The charge level of the fee was calculated as the average uncovered cost per tonne km. The first step was to calculate the uncovered costs of heavy traffic (i.e. costs not already borne by the owner directly or in the form of taxes and charges). This included uncovered road infrastructure costs and external costs caused by heavy vehicles. Damages caused by congestion or the greenhouse effect were not considered. The external costs were found from studies and were divided into three areas that could be given monetary values; air pollution, noise and accidents. (Balmer, 2003)

This was then divided by tonne km to obtain the level of charge. The fee varies according to three factors: distance (kilometres travelled on Swiss territory), weight (admissible weight of vehicle and trailer) and the emissions of the vehicle. Therefore the HVF is calculated by:

Rate x Distance travelled in Switzerland x Weight of vehicle and trailer x Emissions Factor

Two systems were developed; one for domestic and one for foreign vehicles, in order to gather the relevant data. Each domestic vehicle has to be fitted with an on board unit (OBU) which is connected to a tachograph, that enables the OBU to register the kilometres driven. The installation of an OBU is not mandatory for foreign vehicles, but is available on request. For an unequipped vehicle, the fee is registered by using an identification card at the special terminals for HVF clearance. Thus the technology is simple and relatively inexpensive, but can only handle a single charge per km for each vehicle type – no differentiation in time and space is possible.

Balmer (2003) states there are three reasons why the charge was politically acceptable. Firstly, it was introduced at the same time as the increased weight limits, so the net effect was to leave transport costs roughly unchanged. Secondly there was support for the proposed use of revenue. A large majority of people agreed that up to 2/3 of the revenue from the HVF should be used for improvements in rail infrastructure in the form of the new base tunnels under the Alps, as part of a strategy of shifting goods from road to rail. The remaining 1/3 goes to the cantons where it is used mainly for roads. And finally, one of the strongest arguments in favour of the HVF was its link to the polluter pays principle.

According to Balmer, the combination of the introduction of the HVF in Switzerland with the allowance of heavier vehicles led to remarkable changes within road transport. There was a change in fleet composition because in the year before the introduction of the HVF, sales of heavy goods vehicles increased by 45%. Truck owners saved money as new vehicles belong to the lowest and therefore cheapest emission class and the admissible weight of the trucks in the fleet could be better matched to the actual needs of the market. The HVF system led to a concentration in the haulier industry, either through mergers or closure of smaller firms. Larger firms were able to manage their vehicles more efficiently and avoid empty runs as empty vehicles cost as much as fully loaded vehicles. In terms of road performance, nationally there was a change to the growth trend as annual increases of vehicles on motorways were replaced by a fall after the change from a flat fee to a distance related fee. In transit traffic across the Alps, the higher weight limit led to an increase in articulated lorries, which was almost outbalanced by a decrease in lighter lorries. This meant that the total number of lorries crossing the Swiss Alps in 2001 was stable and is currently about equal to the level before the HVF.

A study after four years found that there were no significant changes in the modal split, rail retaining its unusually high market share. The study states "The new traffic regime has led to a sustained change in the road haulage sector. The trend towards an ever growing number of lorries on the roads has been broken and the negative effect on the environment shows a significant decrease. The rail sector's share of freight remained steady." (Swiss Federal Office for Spatial Development, 2004). McKinnon (2005) stated that once the new trans-Alpine rail tunnels which are largely funded by HVF revenue are opened in 2007 and 2014/15, rail should capture a much larger share of the Swiss freight market.

4.3 Austria

Motorway tolling had existed in Austria since 1968 as the first toll motorway A13 Brenner motorway connected Austria and Italy. The Austrian HGV charge came into force on January 1 2004. It applied to all vehicles exceeding 3.5 tonnes, using the Austrian motorways and expressways. It is based on the distance travelled and the number of axles. The main motivations for the charge were to finance the motorway network and to attribute costs more fairly according to use.

The Austrian system uses a Dedicated Short Range Communication (DSRC) system, which is the main type of microwave system used for road tolling. DSRC is used based on 400 road side beacons distributed across Austria's 2000km autobahn network. Onboard devices (Go-Boxes) are used to communicate with these beacons and track truck movements across the network and calculate the toll level. Tolls are either paid via a centrally registered account or pre-pay by topping toll credit in advance through the internet or sale points. Go-Boxes must be fitted on all vehicles with a gross weight of over 3.5 tonnes travelling on the Austrian motorways (McKinnon, 2005).

Thus Austria represents more sophisticated technology where some differentiation in time and space is possible, but where it would be impractical to charge all roads.

User acceptance is believed to be high due to a user-friendly system, although there are some problems of local traffic diversion to untolled roads. There does not appear to be evidence of other effects.

4.4 Germany

The German heavy goods vehicle (HGV) charge was introduced in January 1 2005, applying to all lorries exceeding 12 tonnes gross weight. The tax is calculated based on the vehicle's environmental status (engine emission levels) and the number of axles.

Rothengatter (2002) explains that the objectives of the HGV charge were to derive fair and efficient user charges for the different vehicle categories using the federal roads and to ensure that charges for infrastructure costs recovered all costs including capital costs and took into account future re-investment cycles, new investment and current expenditures. It was desirable that all users should bear exactly the costs that they were responsible for.

European law (at the time Directive 1999/62/EC of 17.6.99) required that the toll rate had to be based on actual infrastructure costs: 'The weighted average tolls shall be related to the costs of constructing, operating and developing the infrastructure network concerned.' External costs were not included. The vehicle category charge had to be based on the category's average infrastructure cost. It was possible to differentiate the charge by the time of day (peak/off-peak) and by environmental performance (emission category). The German government decided initially to only differentiate according to environmental performance.

By introducing the HGV toll system, the German government believed there will be more rigorous application of the 'user pays principle' to domestic and foreign users. HGVs are responsible for much of the costs of construction, maintenance and operation of motorways, and a distance-based toll will allow HGVs to make a contribution towards infrastructure costs. It was suggested that more efficient use would be made of transport infrastructure capacity due to the tolls (Hahn, 2002).

The German government decided to invite bids for a private sector operator to run the system of upgrading, maintenance, operation and financing. The idea was to have a combination of tolling and public-private-partnership models and the operator has to pre-finance the system. This allows the private operator to receive a share of the tolls collected on a stretch of motorway. There was additional relief for public budgets by switching from tax funded to user funded infrastructure.

The German system mainly relies on satellite tracking to determine the distance trucks travel on the autobahn network. Toll revenue is then collected at the end of each month by direct debit from registered accounts, credit cards or fuel cards. For vehicles without OBUs, payments can be made for particular trips in advance either online or at 3500 toll-station terminals.

Thus Germany has the most sophisticated pricing system of the three countries, which in principle could be extended to cover all roads, and to differentiate in space and time as well as by vehicle type.

The scheme was expected to raise around 3 billion Euros a year, which is proposed to be spent on road and rail infrastructure. One year on since it was introduced, Kossak (2006) states that revenue of 2.86 billion Euros had been generated, which is in-line with the expectations. 23 billion vehicle kms had been travelled in the first 11.5 months, where 35% was travelled by foreign trucks.

According to Kossak, it was found that there has been no traceable increase of transport charges and no significant impact on the structure of the trucking industry. Also there seems to be no traceable impact on consumer prices. There are has been a significant tendency towards a higher average load factor. Rail freight in Germany has increased significantly since introduction of the charge. Some problems have been reported of trucks diverting to untolled routes.

4.5 Conclusions on charging practice in Europe

The three countries discussed above illustrate the range of charging systems possible. The Swiss system of charges linked to tachograph readings is cheap to implement and covers all roads in the country. Thus there is no reason why it could not be adopted throughout Europe. It can differentiate charges according to the type of vehicle, but not in time and space.

The Austrian system of charges based on short range microwave communications requires beacons on all roads charged. Whilst capable in principle of distinguishing between type of vehicle, type of road and time of day, it would be very expensive to install it on other than the main road network.

Finally the German approach is the most flexible of all. In principle it can distinguish type of vehicle, type of road and time of day. However, it is considerably more expensive than the Swiss to install so a cost benefit analysis is needed of whether the improved incentives it gives bring benefits that more than offset the additional costs.

5. Regulation

Both road and rail infrastructure are natural monopolies and thus, although they are predominantly publicly owned (there are some road PPPs in Europe) there remains a risk of overcharging and inefficiency due to a lack of competitive pressure, At the same time simply regulating charges may lead to too little investment, so there is a need to ensure appropriate investment plans as well. European legislation does not currently require a road regulator, but it does for rail and there may be lessons for the road sector from experience of rail regulation. Whilst the main reason why the European Union requires a rail regulator is to prevent discrimination against new entrants (most European countries still have a dominant government owned train operator, and sometimes it is a subsidiary of the same holding company as owns the infrastructure), European legislation also requires there to be a multi-annual investment plan with adequate funding and pressure for efficient delivery. Often this is a direct contractual arrangement between the government and the infrastructure manager, but in some cases the regulator plays a role. That is particularly true in Britain, and the current British arrangements will be the subject of the rest of this section.

Rail infrastructure planning in Britain takes place on a five year cycle, and starts with the government issuing two documents – the high level outputs specification (HLOS) and the statement of funds available (SOFA). The HLOS sets out what the government expects of the rail infrastructure over the coming five years, in terms of capacity, reliability, safety and other key performance indicators. The SOFA sets out the amount of funding the government is prepared to make available. In the light of these documents, the infrastructure manager sets out its business plan, and the regulator examines this to ensure its adequacy to meet the required outputs. The regulator also considers, on the basis of benchmarking studies, to what extent it believes the infrastructure manager should be capable of reducing its unit costs over the coming five year period. Finally the regulator pronounces on whether the HLOS and SOFA are compatible, and brokers changes to achieve this if they are not. Ultimately, if the differences cannot be reconciled, the regulator is obliged by law to reduce the required outputs to be consistent with what the infrastructure can deliver within the funds available if it operates efficiently.

The benefit of this approach is that it provides a five year investment plan, consistent with the available funding, subject to independent scrutiny and with independent judgement, based on in depth research, on costs and benefits and on what the infrastructure manager should be able to achieve in terms of cost reduction (the outcome of a directly negotiated contract between government and infrastructure manager tends to be based on negotiating skills rather than independent research). Once the settlement is reached, the government is committed to providing the relevant funding over the five year period (it used to be the case for rail, and still is for road, that the government would not commit itself to funding for more than a year at a time, making it very difficult to plan and commission investment projects efficiently).

As part of the process, the regulator scrutinises the track access charges proposed by the infrastructure manager, to ensure that they give the right incentives in terms of reflecting marginal cost, and the income they yield is adequate, together with receipts from the government and permitted borrowing, to carry through the plan.

This structure has been seen to be very effective in practice, and the British government now proposes to transfer part of it to the road sector. It proposes that the Highways Agency (the body responsible for the strategic road network) will be converted from a government agency to a government owned company. Thus its staff will cease to be civil servants, giving it flexibility in recruitment and remuneration and at least a degree more management independence. The government itself will remain responsible for setting road user charges and determining investment plans, but it will draw up a five year road investment plan to run in parallel with the rail one, and commit itself to funding for the entire period. Finally the role of the rail regulator will be extended to cover efficiency investigations of roads, in order to advise on how much funding an efficient roads infrastructure company will need to achieve the outputs specified by the government.

6. Conclusions

An efficient heavy goods vehicle charging regime requires that charges be related to marginal social cost. That certainly requires a distance based charge which varies with the characteristics of the vehicle (both in terms of the amount of wear and tear it causes and its environmental impact). Such a charge is relatively cheap and east to implement, using technology along the lines of the Swiss system.

However, this will not reflect the fact that wear and tear depend on the type of road (in particular pavement thickness) and environmental impact on its location (particularly proximity to buildings). Moreover, in European conditions, congestion remains the most important externality even on inter urban roads, and the cost of this varies sharply with location and time of day. Whilst charging on the basis of location and time of day may be achieved for a limited network by microwave technology, and for the whole network by GPS based systems, no European country has yet achieved this for the whole network. The German technology comes closest to making it possible, but charges still only apply to the strategic road network and do not differ by location and time of day.

There is strong evidence that the charges in Switzerland and Germany have influenced load factors and the choice of vehicles, with accelerated introduction of newer more environmentally friendly vehicles, They also do appear to have favoured rail. Both Austria and Germany, where the charges only apply to main roads, seem to have had some problems with vehicles diverting to other roads.

How are charges best regulated? In Europe, even where roads are provided by PPPs, both charges and investment plans continue to be determined by government. But the experience of the rail sector in Britain, suggests that efficiency will be improved if there is an independent regulator, able to scrutinise the efficiency of the road provider and the consistency of the investment plans and budget of the government to ensure that efficient road user charges are combined with a consistent and efficient investment plan.

References

Arsenio, E. 2002. The Valuation of Environmental Externalities: A Stated Preference Case Study on Traffic Noise in Lisbon. PhD Thesis, University of Leeds, Institute for Transport Studies, Leeds.

Bak M, Borkowski P, Musiatowicz-Podbial G, Link H. 2006. Road infrastructure cost in Poland, Annex 1.2C to Deliverable D3, Marginal cost case studies for road and rail transport. GRACE (Generalisation of Research on Accounts and Cost Estimation). EU-Project funded by Sixth Framework Programme. ITS, University of Leeds, Leeds.

Balmer, U. (2003) Practice and experience with implementing transport pricing reform in heavy goods transport in Switzerland, IMPRINT-EUROPE

Bickel P, Hunt A, De Jong G, Lair J, Lieb C, Lindberg G, Mackie P, Navrud S, Odgaard T, Shires J, Tavasszy L. 2006. Proposal for harmonised guidelines. Deliverable D5 HEATCO. Funded by Sixth Framework Programme. Stuttgart. http://heatco.ier.uni-stuttgart.de/ 2006-10-25.

Capros P, Mantzos L. 2000. Kyoto and technology at the European Union: costs of emission reduction under flexibility mechanisms and technology progress. International Journal of Global Energy Issues, 14, pp.169-183.

Commission of the European Communities. 2007 Communication on Limiting global climate change to 2 degrees celsius, COM (2007) 0002 FINAL. Brussels.Commission of the European Communities.

De Blaeij AT, Florax RJ, Rietvield P, Verhoef ET. 2003. The Value of Statistical Life: a Meta Analysis. Accident Analysis and Prevention, 35(6), pp. 973-986.

DEFRA 2007. How to Use the Shadow Price Of Carbon in Policy Appraisal. London.

Delucci, M., McCubbin, D. 2010. External Costs of Transport in the U.S. In: De Palma, A., Lindsey, R., Quinet, E., Vickerman, R. (Eds): Handbook on Transport Economics, Edward Elgar Publishing.

ECMT 1998. Efficient transport in Europe, Policies for internalisation of external costs. European Conference of Ministers of Transport. Paris.

Galilea, P. , Ortuzar, J de D. 2005. Valuing Noise Level reductions in a residential Location Context. Transportation Research Part D, 10, pp. 305-322.

Hahn, W (2002) Implementing transport pricing reform in Germany, Federal Ministry of Transport Building and Housing, IMPRINT-Europe

Haraldsson M. 2006. Marginal cost for road maintenance and operation – a cost function approach. Annex to Deliverable D3 GRACE, Marginal cost case studies for road and rail transport. Funded by Sixth Framework Programme. ITS, University of Leeds, Leeds.

Holland M, Pye S, Watkiss P, Droste-Franke B, Bickel P. 2005. Damages per tonne of PM2,5, NH3, SO2, NOx and VOC's of Eu25 Member State (excluding Cyprus) and surrounding seas. Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe(CAFE) programme.

Hurley F, Hunt A, Cowie H, Holland M, Miller B, Pye S, Watkiss P. 2005. Methodology for the Cost-Benefit analysis for CAFE: Volume 2: Health Impact Assessment. Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe(CAFE) programme.

INFRAS, CE, ISI and University of Gdansk 2008. Handbook on estimation of external cost in the transport sector. Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT). Delft.

IVM, BIO, Ecologic, GHK, PSI, TME, VIT 2006. Ex-post estimate of costs to business of EU environmental legislation. Final Report, EU Directorate General of the Environment, Institute for Environmental Studies, Amsterdam.

Jonsson L, Haraldsson M. 2008. Marginal Costs of Road Maintenance in Sweden. Annex 1 to CATRIN (Cost Allocation of Transport Infrastructure cost) Deliverable D6 Road Cost Allocation for Europe: Recommendations and open questions. Funded by the Sixth Framework Programme. VTI, Stockholm.

Kossak, I.A (2006) The German Experience of HGV tolling, Presentation on 25th April 2006 at IMPRINT-Net Interurban Road Expert Group Meeting 1

Lemp, JD, Kockelman, KM. 2008. Quantifying the External Costs of Vehicle Use: Evidence from America' Top –Selling Light-Duty Models. Transportation Research Part D, 13, pp. 491-504.

Lindberg G. 2002. Marginal Costs of road maintenance for heavy goods vehicles on Swedish roads. UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Deliverable 10, Annex A2. Funded by EU 5th Framework RTD Programme. ITS, University of Leeds, Leeds.

Lindberg G. 2006. Marginal cost case studies for road and rail transport. Deliverable D3 of GRACE(Generalisation of Research on Accounts and Cost Estimation). EU-Project funded by Sixth Framework Programme. ITS, University of Leeds, Leeds.

Link H. 2006. An econometric analysis of motorway renewal costs in Germany. Transportation Research Part A, Vol. 40, pp. 19-34.

Link H. 2009. Marginal costs of road maintenance in Germany. Annex 3 to Deliverable D6, Road Cost Allocation for Europe: Recommendations and open questions. CATRIN (Cost Allocation of Transport Infrastructure). EU-Project funded by Sixth Framework Programme. VTI, Stockholm.

Link H, Nilsson J E. 2005. Marginal Infrastructure Costs. In : Nash CA, Matthews B (Eds.) : Measuring the marginal social costs of transport. Research in Transportation Economics, Vol. 14, (Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo: Elsevier).

Link,H, Nash C A Ricci A and Shires J D (2014) A generalised approach for measuring the marginal social costs of road transport in Europe. International Journal of Sustainable Transport.

McKinnon, A.C (2005), Application of road-user charging to trucking operations in Europe: A review of the tolling schemes and assessment of their possible impact on logistics systems, Conference Proceedings Logistic Research Network 2005, Plymouth

Nash C.A.; Menaz B.; Matthews B. 2008. Inter-urban Road Goods Vehicle Pricing in Europe Road Congestion and Pricing in Europe: Implications for the United States , pp.233-251 (published by Edward Elgar edited by Harry Richardson and Chang-Hee Bae)

Navrud S. 2002. The state of the art on economic valuation of noise. Oslo.

Nellthorp J, Bristow AL, Day B. 2007. Introducing Willingness-to-pay for Noise Changes into Transport Appraisal: An Application of Benefit Transfer, Transport Reviews, 3, 27, pp. 327-353.

Parry, I.W.H, Walls, M., Harrington, W. 2007. Automobile Externalities and Policies. Journal of Economic Literature, Vol. XLV, pp. 373-399.

Pearce, D. 2003. The Social Cost of Carbon and its Policy Implications. Oxford Review of Economic Policy, 19, pp. 362-384.

Proost S, van Dender K. 1999. TRENEN II – STRAN – Final report for publication. Study funded by the 4th Framework Programme of the European Commission, Leuven.

Prud'homme R , Bocarejo JP. 2005. The London Congestion Charge: A Tentative Economic Appraisal. Transport Policy, 12, pp. 279-287.

Prud'homme R, Kopp A. 2006. The Stockholm toll – an economic evaluation. University Paris XII and University Paris I (Sorbonne). Paris.

Rizzi LI, Ortuzar J de D. 2006. Estimating the Willingness-to-Pay for Road Safety Improvements. Transport Reviews Vol. 26, No. 4, pp. 471–485, July 2006.

Ricci A, Enei R, Piccioni N, Vendetti A, Shires J. 2008. GRACE (Generalisation of Research Accounts and Cost Estimation), Deliverable D7, Generalisation of Marginal Social Cost Estimates. Funded by Sixth Framework Programme, ITS, University of Leeds, Leeds.

Rothengatter, W (2002) Charging systems for the use of transportation infrastructure, Institute for Economic Policy Research (IWW)

Schreyer C, Schmidt N, Maibach M. 2002. Road econometrics – Case study motorways Switzerland. UNITE (UNIfication of accounts and marginal costs for Transport Efficiency) Deliverable 10, Annex A1b. Funded by EU 5th Framework RTD Programme. ITS, University of Leeds.

Sedlacek N, Herry M. 2002. Deliverable 10: Infrastructure Cost Case Studies, Annex A1c: Road econometrics – Case study motorways Austria, UNITE (UNIfication of accounts and marginal costs for Transportation Efficiency), ITS, University of Leeds, Leeds.

Stern, N. (2006). The Economics of Climate Change. HM Treasury, London.

Swiss Federal Office for Spatial Development (ARE) (2004), *Fair and Efficient: The distance-related Heavy Vehicle Fee (HVF) in Switzerland,* Berne

Van Vliet D. 1982. SATURN – a modern traffic assignment model. Traffic Engineering and Control, 23, pp 578-581, Dec.

Wardman, M, Bristow, A. L., Arsenio, E. 2005. Applying Stated Preference Methods to the Valuation of Noise: Some Lessons to Date. Paper prepared for the Congress and Exposition on Noise Control Engineering, 7-10 August, Rio de Janeiro, Brazil.

Wardman, M, Bristow, A. L. 2008. Valuations of Aircraft Noise: Experiments in Stated Preferences. Environmental and Ressource Economics 39(4), pp. 459-480.

Watkiss P, Anthoff D, Downing T, Hepburn C, Hope Chr, Hunt A, ToL R. 2005. The Social Cost of Carbon (SCC) Review - Methodological Approaches for Using SCC Estimates in Policy Assessment. Final Report November 2005. Research on behalf of DEFRA,UK

Whaba, M., Hope, C. 2006. The Marginal Impact of Carbon Dioxide Under Two Scenarios of Future Emissions. Energy Policy 34, pp. 3305-3316.