

Tolling Heavy Goods Vehicles on European Roads. From a Diverse Set of Solutions to Interoperability?

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This paper is based on work carried out in the DESIRE research project of the European Commission's 5th Framework Program, dedicated to the identification of preferred schemes for inter-urban tolling of Heavy Goods Vehicles (HGV's) in the EU. As such, it presents some of the current developments related to this type of tolling, starting with the relevant transport policy background and a brief review of the various forms of tolling in existence and the main technological approaches used for tolling operations.

A variety of situations in different countries studied in the project is then reviewed and presented in a framework that tries to put them in perspective according to several angles, accompanied by some explanation of the choices made in the various countries. A synthesis of this complex set of realities is produced thereafter in the form of a suggestion for a preferred form of pricing scheme.

Recognising that various background conditions have led to legitimately different choices, but also that interoperability of each vehicle across regional and national borders is a natural request in international freight transport, the issue of the real value and costs of interoperability is finally discussed. It is argued that political difficulties for approval of these schemes at national level have been so strong that the policy package presented for parliamentary approval generally has to be very well tuned to the prevailing balances of power, thus leaving the issue of interoperability to a later stage. This evolution is currently of a relatively easy conceptual formulation, but many institutional and economic hurdles must be expected along the way. It is expected that interoperability may be reached within some 10 years, when there will be joint pressure for it from the demand side (hauliers) and from the supply side (technology suppliers).

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Acronyms / Abbreviations used

AVI	Automatic Vehicle Identification
CEN	Centre Européen de normalisation / European Centre for Standardisation
DAREA	One of the basic forms of IRPS, in which the price is based on the amount of kilometres driven within a certain perimeter (all roads in that perimeter are charged)
DSRC	Dedicated Short Range Communication
EU	European Union
EFC	Electronic Fee Collection
GPRS	General Packet Radio Service (an evolution from GSM, non-voice value added service that allows information to be sent and received across a mobile telephone network)
GPS/GNSS	Global Positioning System / Global Navigation Satellite System
GSM	Global System for Mobile Communications (a second-generation mobile phone standard adopted in the EU)
HGV	Heavy Goods Vehicle
IRPS	Interurban Road Pricing Scheme
LPR	License Plate Recognition
NET	One of the basic forms of IRPS, in which the price is based on the kilometres driven on a net of interrelated motorways of the same hierarchy-level
OBU	On-Board Unit
PERM	One of the basic forms of IRPS, in which the charge is levied for the permit to drive within a certain perimeter for a limited time period
UMTS	Universal Mobile Telecommunications System (a third-generation mobile phone standard, with higher service and data speed possibilities)

1. Introduction

At the EU level, pricing policy in the transport sector plays an increasingly important role. The EU „Green Paper“ on fair and efficient prices (EU 1995) advocates the pan-European internalisation of external costs in terms of air pollution, noise, congestion, accidents and impacts on human health. The specialists of the „High Level Group on Infrastructure Charging“ appointed by the European Commission have shown how the different existing transport pricing systems could be adapted towards a more coherent system which is compatible with the principles of the „Green Paper“. This work was the basis for the White Paper on „Fair Payment of Infrastructure Use“ (EU 1998). The White Paper stresses the idea of social marginal cost pricing and proposes as a first step that transport infrastructure users should cover the infrastructure costs they actually cause. This should encourage a more efficient use of the road network, thus helping to relieve traffic congestion. In its second

report the High Level Group was concerned intensively with the procedure and methodology of estimating the costs relevant for the determination of prices.²

The above mentioned activities have one common objective: A more efficient transport pricing system should contribute to both the competitiveness of the European economy and to a more sustainable transport system in Europe. As a consequence of the emphasis on efficiency, pricing principles of the economic welfare theory became the focus of attention. These principles say that with a given infrastructure the price for the use of infrastructure should correspond to the short run social marginal cost. Such pricing would maximise the social surplus, i.e. the sum of the producers' surplus (= the profits of private and public transport enterprises) and the consumers' surplus. According to this principle a heavy goods vehicle (HGV) should pay the additional costs it causes by using the road network, namely costs of reconstruction and pavement, wear and tear and maintenance as well as congestion costs and transport system external costs.

Besides this objective of efficiency, there are also issues of competitiveness between countries and fiscal fairness within each country that must be considered in relation to supporting the investment and maintenance costs of motorways in Europe:

With the objective of financing motorway construction at least partially out of the State budget (and thus bringing forward the dates for their opening to service and cost reductions for industries), a few countries in southern Europe have had tolled motorways (where all vehicles have to pay) for some decades;

With the increase in international goods traffic, it is recognised that a stronger application of "user pays" principle is necessary in relation to maintenance costs, thus pricing access to the motorway of those vehicles which bear a clear responsibility for those costs, i.e. heavy goods vehicles. Initially this led to the introduction of vignettes as an instrument for these charges, but it was quickly recognised that, by pricing the right of access instead of real use, the inherent unfairness of the instrument also limited its financial dimension.

Albeit for partially different reasons, some countries (Holland, Germany and Austria) have decided to move to a distance based price. In the meantime, Dutch governments have shelved this decision, but Germany and Austria have kept it. Real operation is expected to start in Austria in January 2004, and has been delayed in Germany by technical problems.

So, the introduction of road charges, in general as well as in particular for HGV's, may be justified with several objectives (not just maximising economic efficiency), which in turn leads to different choices in some of the key dimensions of the charging schemes.

The aim of the DESIRE (Designs of Interurban road pricing schemes in Europe) project was to provide a practical assessment of the effectiveness, the feasibility and the impacts of different interurban road pricing schemes (IRPS) for heavy goods vehicles (HGV's) in Europe.

One of the specific goals in DESIRE work was to identify and describe possible ways to adopt IRPS with reference to practical problems that may emerge as they are implemented in different contexts. Solutions that may reduce the gap between socially optimal pricing policies and their technical and organisational feasibility should be identified and described. This paper deals with the following issues:

² See High Level Group on Transport Infrastructure Charging (1999), Final Report on Estimating Transport Costs.

- description of present and future domestic IRPS, with relation to the context in which they are to be implemented
- discussion of problems/solutions and identification of likely impacts from their introduction in different national contexts
- understanding whether/under which conditions domestic IRPS can support the adoption of relevant European concepts

To that effect the basic concepts for analysis of IRPS are outlined next, after which a description of the European situation in terms of IRPS implementation is provided, followed by discussion on implementation of preferred schemes, as it relates to the different European contexts. Finally, the issue of interoperability is tackled, discussing the technical barriers, the costs and the added value it provides, and a likely path towards interoperability is suggested. This paper was initially presented at the IMPRINT conference in May 2002, but the evolution of events until the time of writing the final version for publication on the journal (December 2003) has led to the addition of some additional elements of information.

2. Dimensions of Differentiation

Four main types of objectives have been identified to justify the introduction of road tolls:

- Financing a transport network upgrading or expansion program (including privatisation of roads as an instrument for public budget relief)
- Internalising external effects of transport
- Management of traffic flows (to fight congestion or even contain demand growth)
- Fair competition among transport modes (allowing for cross-subsidies between transport modes, to compensate for other distortions)

Besides allowing pursuit of one or more of these objectives, introduction of road tolls will allow approximation between the point of generation of costs (road maintenance, environmental aggression, congestion) and the generation of associated revenue, thus allowing not only variabilisation of the charges in line with the costs generated, but also a better allocation of those revenues if so wished.

Depending on the existence and weight of these objectives, there will be different choices about price levels, price variability and price incidence.

2.1 Basic forms of IRPS

Depending on three variables (the infrastructure subject to a charge, the vehicle differentiation and the time dependency of the charge), we can then have the following main basic forms of interurban road pricing schemes:

- DAREA: Distance-dependent area pricing, based on the amount of kilometres driven within a certain perimeter.
- NET: Distance-dependent network pricing, based on the kilometres driven on a net of interrelated motorways of the same hierarchy-level.
- COR: Cordon pricing, based on tolls for entering and/or exiting a cordon around a defined urban area.

- PAS: Passage tolling: the toll is levied for the use of a specific facility like a bridge or tunnel.
- PERM: Driving permit: the charge is levied for the permit to drive within a certain perimeter for a limited time period.

From these, only DAREA, NET and PERM are directed at systematic application for inter-urban traffic, the two first being based on distances actually travelled, and thus allowing a better tuning between the costs generated and the toll applied.

All these three forms are currently in existence in Europe:

- NET is the traditional form of motorway tolling, applied for several decades in France, Italy, Spain and Portugal;
- DAREA is the newly launched Swiss scheme for charging HGV in all roads in its national territory;
- PERM is the basis of the current Eurovignette scheme (a stamp allowing circulation in all motorways of a given country or group of countries for a specified period of time) in place in Germany, Benelux and Denmark.

2.2 Technical and procedural design elements

As regards the technical elements, there is not a single fee collection system but almost as many systems as there are applications. The systems differ in many respects such as:

- Vehicle categories that are subject to the fee: e.g. all vehicles or only heavy vehicles,
- Road infrastructure which is subject to charging (e.g. all roads or motorways only),
- Time modulation of the tariff, for all vehicles or only for a specific group of vehicles, on all the network subject to tolling or only in specific sections,
- Traffic operation at point of charging: single lane operation with or without stopping of traffic versus multi lane operation with unhindered traffic flows,
- Type of technology for localisation and charging: localisation and data communication at the point of charging by means of dedicated short range communication (DSRC) or localisation by means of satellite navigation (GPS/GNSS) and cellular network communication (GSM, GPRS, UMTS, TETRA),
- Payment mode: manual fee collection using cash or bank card, automatic fee collection using magnetic card or chip card, electronic fee collection using on-board equipment,
- Payment means: cash, electronic purse, token, subscription,
- Enforcement: opening of barrier after completed fee transaction versus principle of self-declaration based on the obligation of the user to participate in the fee collection process and enforcement by means of automatic license plate reading.

It would go beyond the scope of this paper to display all detailed information on technical and procedural design elements here.

The existing and planned toll collecting systems in the European Countries are very different regarding the technique in use. Basically there are three different kinds of technology used for EFC:

Dedicated Short Range Communication (DSRC):

The most common technology for EFC is DSRC, which is based on European and international standards. DSRC works with road-side equipment beacons which communicate with an On-Board Unit (OBU) fixed to the vehicle windscreen, via low-power microwave or infra-red transmission. The DSRC is commonly used in one-lane configurations and has been adapted to multi-lane use, in for instance Italy, France, Portugal and Spain. This is a mature technique. The system is highly accurate, but is bound to relatively costly roadside equipment.

Autonomous Systems:

Autonomous systems work without dedicated road-side equipment and use GPS-receiver (GPS means Global Positioning Satellite system) to locate the position of the vehicle and GSM (Global System for Mobile Communications) technology for communication. In a relatively short term, successive generations of mobile phone technology like GPRS (General Packet Radio Service) and UMTS (Universal Mobile Telecommunication System) probably will be part of Autonomous Systems. Identically, localisation will likely be available with the European GNSS (Global Navigation Satellite System) Galileo, and not necessarily dependent on the American GPS. As soon as the accuracy and localisation have been improved this system is flexible and can be used without any roadside equipment, but with a central management system. The IRPS application is flexible in use and can be changed easily by mapping a new tolling area or road based on co-ordinates. The present roaming system between telecom providers makes a European system possible. Some worries about the technical and procedural reliability of such systems for actual pricing are still frequently expressed, but any such problems should be solved within a short time of “warming up” of the systems.

Automatic Vehicle Identification (AVI):

These systems are based on video-cameras and License Plate Recognition (LPR). There is no vehicle equipment necessary. All vehicle data is stored in the background system. AVI is mainly used for enforcement (in case the main classification / identification technology fails). The imaging software and hardware have been improved, but nevertheless the system always has a failure rate, which makes it necessary to use a manual check.

From the above it is clear that there is not a single universal best approach to inter-urban road pricing for heavy goods vehicles in Europe. This is due not only to legislative reasons but also to different objectives of introducing IRPS, which have an influence on the choice of system, (e.g. for financing roads, for management of traffic volumes or for covering marginal social costs). Nevertheless, to ensure easy and free movements of goods as well as fair competition between transport modes and between countries, some level of interoperability between different systems is desirable. Therefore, aspects of long-term convergence of different solutions are discussed in the following sections.

The issue of privacy protection, while very important for pricing of passenger cars, has not raised any significant barriers in the discussions leading to tolling of HGV's. In any case, many haulage firms already have permanent systems tracking the location and paths of their trucks.

3. Current situation in various European countries

3.1 Solutions for different European contexts

Given specific structural circumstances in different countries, national objectives, constraints and institutional/regulatory settings DESIRE conceived and designed a reference scenario. This served the purpose of outlining a plausible picture in mid term evolution of a variety of national approaches to the development or implementation of IRP schemes in Europe. The countries studied in the project are a set representing all major situations in Europe, although not (like it always happens in similar research projects) covering all the EU space.

Information reported for each national context³ was reviewed and submitted to a sequence of logical tests aimed at identifying:

- forms of IRPS that are on place or can be expected to be so by the year 2005 as a result from national decisions;
- pricing schemes that are implemented or could allow implementation;
- institutional arrangements for this implementation.

As shown in Box 1, the DESIRE sample is representative of three clusters within which basic approaches can be grouped with reference to historic traditions and new plans to levy charges for the use of roads in the European Union. It also includes the non-EU countries Switzerland and Hungary.

Information reported for each national context was reviewed and processed to identify where electronic IRPS can be expected to be in operation in Europe by year 2005 as a result of irreversible national decisions concerning implementation of new schemes and further development of those already in operation in EU countries with tolling tradition, and Switzerland and Norway. The information available did not allow a detailed scrutiny of the reasons why each country decided on its specific configuration of road charges, so an interpretation of the factual information is presented at the end of section 3.

³ The DESIRE reference scenario has been consolidated by reviewing and processing information reported from eleven (11) national contexts.

*Box 1. Desire clusters of national contexts***Tolled motorways (long tradition - EU country)**

France and Portugal two countries that relied on tolls since early stages in the development of their high standard road network. In both countries a common system (T.I.S and VIA VERDE) is operated by a variety of concessionaires in order to collect tolls without requiring vehicles to stop at toll stations (NET). In both countries alternative approaches are being considered/introduced to share with private sector the costs and risks of road infrastructure project financing schemes.

Tolled roads (short tradition – Non-EU country)*Switzerland*

The first country in Europe in which a DSRC based system was implemented to charge infrastructure and environmental costs according to actual mileage performed by HGV's on the whole national road network (DAREA). Revenue from the Swiss LSVA is also a main source to fund investment on strategic transalpine tunnels and rail systems.

Hungary

The accession country that pioneered motorway project financing through tolls immediately after political change in Central Europe; with sustained investment necessary to develop high standard road networks, a step wise process is now being implemented to prepare for country wide implementation of distance based motorway charges starting with the introduction of electronic based monitoring of Eurovignette (PERM).

Mature for introduction of tolls

Austria and Germany, where the development of electronic IRP schemes went out on tender to substitute vignette (PER) with pricing schemes to charge HGV's as a function of actual mileage on motorways with no reliance on toll stations (NET).

Also *The Netherlands* has planned to substitute Eurovignette with a system to charge HGV's as a function of mileage performed on national motorways; in continuity with plans developed in the last decade, the Dutch scheme is the only one in continental Europe specifically conceived to introduce interurban road pricing to support demand management/increase accessibility, and thus charging all vehicles on all roads. But this plan has been the object of heavy criticism and subsequent Governments have shelved it.

Newcomer (Nordic countries)

Denmark, Finland, Norway, Sweden, quite an integrated regional economy with common approaches to both environmental motor fuel taxation and Eurovignette; Norway also has a long-standing tradition in electronic pricing around urban areas (COR) to fund investment on local road networks.

3.2 Results from the national tests

Reversibility

The degree of reversibility of national options concerning IRPS was rated on the basis of:

- status of national IPRS schemes: from conceptual outline to an on-going policy process in which key options are subject to government scrutiny/parliament approval, then to launch of tenders, to selection of developers and implementation up to actual operation.
- context maturity: the degree (low, medium, high) a new IRPS scheme is suitable to meet national objectives/constraints, - or modifying/further evolving one that is on place - requiring minimum, moderate or radical/controversial changes to existing legislative, institutional and regulatory frameworks.

By coupling these two sets of circumstances, different national IRPS have been positioned within the following “reversibility” matrix illustrated in Table 1.

Table 1. Rating reversibility of national decisions on electronic IPRS scheme according to status in decision making process and degree of maturity of domestic context

Stage in e-IRPS development	Context maturity		
	Low	Medium	High
1) Conceptual	Finland	Hungary	Denmark, Sweden
2) Under political scrutiny		Netherlands	
3) Out on tender			
4) Decided/ Under implementation	Germany		Austria
5) In operation			Switzerland
6) Mature		France, Portugal	Norway

According to this rating, only the four (4) electronic systems already in operation in France, Portugal, Norway (mainly urban pricing), plus Switzerland and Austria should be assumed as ‘irreversible’ in DESIRE.

Uncertainty

Based on national reports, the reasons behind present uncertainties in IPRS development have been grouped into five (5) broad categories.

- a. barriers/unsolved problems in domestic decision making
- b. concerns on regional development, related to the fact that changes to present IPRS schemes are expected to have different impacts on traffic and/or economic performance of different regions, including financial resources available to concerned constituencies
- c. cost effectiveness of alternative IPRS configurations (e.g. DAREA Vs NET) and/or their extension over space and/or timing in their implementation
- d. uncertainty concerning technology choices,

- d1. either to keep a window open for more promising technologies to become available, or
- d2. to wait for a critical mass being reached in the single market/neighbouring countries.

It must be noted that these uncertainties do not relate exclusively to introduction of road tolls but also to evolutions of tolling systems already in place. As summarised in Table 2 - in which a weight (from X to XXX) is given to different types of uncertainty – the first three types of uncertainty (a, b, c) are internal in nature i.e. deal with domestic IRPS dossiers. On the other hand, even the most determined/ready to implement/further develop an electronic IRPS governments may have limited, if any, control on the latter two types of circumstances (d1, d2). Countries in this table are listed according to the clusters used in box 1.

Table 2. Main reasons behind present uncertainty

	Internal			Exogenous		
	Barriers in national decision making (a)	Regional impacts (b)	Cost-Effectiveness (c)	Uncertainty on technology Technical progress (d1)	Other Critical mass (d2)	Other (e)
Portugal		X	X			
France		XX				
Switzerland		X				
Germany				X		
Netherlands	XX		XX	X	XX	
Denmark/ Sweden/Finland	X		XX		X	
Norway			X		X	
Hungary						X

All in all, the outcome from these uncertainty tests is consistent with our previous rating of reversibility. Jointly taken, the two tests would point out that:

- national decisions in the cluster of ‘mature for introduction of tolls’ (the Netherlands, but previously also for Germany) are by far the most critical for development of electronic IPRS in the near future
- poor cost effectiveness is the main reason for generalised adoption of electronic IRPS not being considered as a high priority in Nordic countries (covered in the same case study in DESIRE)
- cost-effectiveness is also a concern in Germany, Portugal and the Netherlands
- in many countries (including those where electronic IRPS systems are in operation) regional impacts of alternative system configurations are key issues in national dossiers.

Technical standards & critical mass

National tests to consolidate the DESIRE reference scenario were also completed having in mind that “after official voting on August 2001 a solution was eventually reached for a

preferred CEN standard for Electronic Toll⁴ Collection” (McKenna, 2001). Also the fact that the European Transport Policy 2010 White Paper is anticipating the intention of the commission to introduce a new directive on interoperability of electronic toll systems on the Trans-European road network by 2002 would confirm that, after years of struggles, the European Commission thinks that conditions are ripe for adopting common standards of road pricing systems in Europe.

Combination of recent decisions to re-focus the Galileo programme from strategic objectives to more commercially oriented ones, together with the fact that GNSS is the key technical option in the German system and the (presented and then abandoned) Dutch scheme – suggest that a commercial market for GNSS applications is spreading, which includes the road haulage European industry.

Given both location and size of the country, finalisation of implementation of the system to levy electronic charges on German motorways has rather strong implications for IRPS diffusion in Europe. The proposal for a Directive on EFC interoperability presented in April 2003 by the European Commission [European Commission, 2003] is based on the adoption of satellite-based EFC solutions for the whole of the EU, although allowing continued operation of DSRC based systems until 2012, and a review of technology and market conditions in 2007. This rather strong position in favour of a technology which is not yet in operation (in particular for technical problems) and discarding a well installed and cheaper option has met rather strong opposition from many sides, in particular from current motorway operators.

National policies and future evolution of IRPS

With the exception of the Austrian IRPS, the only new electronic system estimated in DESIRE to be in operation by year 2005, the DESIRE reference scenario is basically a ‘business-as-usual’ one, since all national reports confirm that no significant changes should be expected to present national schemes for road transport taxation and charges in the next years, nor to associated institutional arrangements.

Specifically, the review of DESIRE national reports confirms that decisions concerning IRPS development, other than influenced by specific structural circumstances on place in different contexts, are integral components of national approaches toward road development, funding and pricing as well as associated institutional settings.

Circumstances in place also point out that future policies in these areas are deeply rooted in present constraints to public budgets and present patterns in distributing responsibility/powers/risks among different subjects: government bodies, motorway concessionaires and private sector.

In the next section an attempt is made to identify possible evolutionary paths on the basis of specific arrangements in countries with experience in tolled motorway concessions and in those considering substituting vignette with electronic IRPS.

National circumstances and IRPS forms

The comparison of actual national options confirms that:

⁴ The more generally used term is “Electronic Fee Collection”, covering wider applications than just road tolls

- national decisions concerning IRPS are strongly determined by financial needs given both present constraints in public budgets and increasing costs in road maintenance, upgrading and investment (old age of many roads, increasing traffic volumes);
- financial constraints do matter to select pricing criteria that, as a rule, are set to cover average road infrastructure costs;
- in contexts where HGV charges are levied (either manually or automatically) to internalise environmental costs besides infrastructure costs, this will likely generate a surplus revenue, except in regions with low traffic volumes;
- revenue maximisation (cost effectiveness) is also a key concern in both decisions concerning spatial extension / configuration of road networks (DAREA vs NET) and when decisions are at stakes to substitute vignette (PERM) with distance based systems to charge HGV.

Even if almost all the national reports indicate that traffic problems (observed in the interurban road network) are regional in nature, present national plans are not tailored to fine tuning the extension of road networks subject to charges in accordance with traffic densities and/or to gradually introduce new electronic IRPS over time e.g. starting from more congested links/networks. Nor are such circumstances explicitly taken into account to modify existing IRPS e.g. to extend tolls from motorways to other roads where it is considered suitable for maximising revenue/optimising traffic conditions on the whole area network. Reasons behind modest consideration of functional patterns in traffic in IRPS design and development may be due to present domestic patterns in distribution of responsibility for road investment and charges among different subjects. The possibility is also suggested that future evolution of domestic arrangements is limited/constrained by present rules for infrastructure charges in the EU.

So, use of short run marginal social cost pricing is not a central feature in these tolling systems, although it may be argued that some of the underlying logic may be found in the fact that the “second generation” of tolling countries is mostly considering application of tolls only to HGV’s and not to all motorised vehicles. The explanation for this modest presence is simple: most governments have other objectives beyond maximisation of efficiency (generation of revenue prevailing among all others) and they would be less effectively achieved with pricing levels based on marginal costs. Moreover, the generalisation of electronic fee collection will facilitate introduction of tariff differentiation according to traffic conditions at a later stage, thus bringing some flavour of marginal social cost pricing into the system.

Detailed comments concerning how structural circumstances (network development and traffic patterns (characteristics)) and financial constraints are influencing decisions concerning infrastructure charges and IRPS forms in different contexts are listed below.

Apart from Hungary, where substantial investment on high standard roads is necessary to anticipate economic and regional growth, national reports would confirm that in all the countries in the DESIRE sample, mature, relatively dense high standard road networks are the backbone of national transport systems, including in terms of stronger concentration of HGV's traffic. With the exception of France and Portugal, in none of them major road investment plans are considered to expand the high standard road networks. In most of them new approaches are emerging to upgrade existing roads, further integrate regional road networks of different standards and/or to smooth bottlenecks through punctual investment.

Regardless of the amount of investment planned to expand high standard roads, financial needs “beyond the capability of national budgets” are considered a tight constraint in Austria, Germany, France and Portugal. In all these countries, full cost recovery (average costs) is pursued to fund domestic road investment, renewal and maintenance of road networks, and especially so of high standard ones (motorways and expressways). In both France and Portugal frameworks are on place for attracting private finance to new road projects.

In Hungary, the fact that the Build-Operate-Tender scheme implemented at the beginning of the 90' to build a new motorway up to the Austrian border proved not sustainable in both financial and social terms, is not a secondary reason behind the decision of relying on vignette to charge HGV's. The fact that the national Development Bank is responsible for setting on a year-by-year basis conditions to fund road development should also be considered indicative of problems faced in accession countries to raise the huge amount of finance necessary to anticipate investment on high standard roads.

On the other side, financial problems are not a concern in both the Netherlands and Switzerland. Within consolidated arrangements to build up transport funds, in both countries charging HGV's has proved/is expected to result into surplus revenue.

In the presence of systematic congestion on the motorway network and ‘absolute’ scarcity of land for new construction (in both the most densely populated metropolitan region and in rural ones) the introduction of an electronic pricing system for making the most of existing road capacity has been in the agenda of the Dutch government for more than a decade. Also in current IRPS plans variations of charges over time/over space are considered a key feature ‘to increase accessibility’. With motorway network extension remaining virtually unchanged, in the last decade substantial investment was engaged to combine selective, on-site expansion of road capacity with IT systems to support demand management.

The Dutch approach is also the only one in which ‘fiscal neutrality’ is considered a strict specification for the introduction of distance based electronic charges to be accompanied with a reduction of the other fiscal charges (purchasing and ownership of passenger vehicles and duties on fuel).

The Swiss approach is confirming that surplus revenue can be expected from full internalisation of HGV's infrastructure charges. In the absence of congestion and plans to expand road capacity, such revenue has become an important additional source for funding the construction of alpine railway tunnels and improving capacity and standard of the national railway system.

In the absence of both significant congestion problems and major plans to expand the road network, the main reason behind the fact that decisions to implement electronic IRPS on interurban roads have not an high priority in the agendas of national governments in Nordic countries may be that associated additional investment costs are not expected to be compensated by higher revenue flows than those from present national schemes for environmentally conscious motor fuel taxation.

As for IRPS forms, previous analysis seems to confirm DAREA as a possible, relevant choice in all countries on the long term when European legislation allows this type of scheme (currently forbidden by Directive 99/62 on “charging of HGV for the use of certain infrastructures”). Nevertheless, with the exception of Switzerland (in which a DAREA scheme was already implemented on the whole national network) all national plans to introduce new electronic IRPS are conceived to start levying electronic charges on motorways (NET). In the absence of reported technical problems for implementing area based network

charges, this could point out either to problems in anticipating investment for installing IRPS at a wider geographical scale, or just reflect present institutional and administrative rules concerning the distribution of responsibilities for national/federal motorways and regional ones.

As a rule, in all the countries the pressure for DAREA instead of (or after some time with) NET configurations has to do with circumstances in place concerning possibility of detours, given network density/alternative routes in different regional areas.

Ex-ante estimates for the Dutch scheme would point out that the macro-economical benefit from DAREA with differentiation to time and place (complex DAREA) is higher than that from a DAREA scheme with flat rates per kilometre. Therefore a complex DAREA scheme should be considered more suitable for demand management purposes.

At present, in DESIREland different rates are charged for different periods only for cars using the motorway network in the Paris metropolitan area during week ends (lower rates before the evening peak on Sundays), and in Portugal for HGV's during off-peak periods, to reduce their concentration of free-access roads.

Almost all national reports point out to significantly different regional patterns in traffic level and concentration – as well as considering different performances of regional economies as a problem in adoption of a nation wide pricing scheme - Portugal seems to be the only context in which compensation schemes are in place (in the form of shadow tolls) to combine the advantages of a national approach to motorways tolling with different patterns in local traffic/circumstances in regional development. (Italy, not in the DESIRE sample, has a similar division between the more developed north and the less developed south).

The previous description of the context(s) in which domestic IRPS is to be implemented and the discussion of the possible impacts resulting from such developments leads in the next section to explore under which conditions domestic IRPS can support the adoption of relevant European concepts, i.e., deriving a preferred form of IRPS for Europe.

4. Deriving a preferred form of IRPS

It is important to differentiate between what is possible in the short term and what would be desirable in a long-term perspective.

Short-term perspective

In the short-term perspective, two criteria describing initial situations seem to pop out as being most relevant: legal restraints on European and national level and the existence of a motorway tolling culture. For EU-member states, both criteria indicate NET tolling to be the basic model from where any particular scheme should be developed. Because of its tradition, legal compatibility with the present EU legal framework, ease of control and the possibility of allowing service differentiation, NET tolling appears to be the most sensible starting point. Only for non EU-member states like Switzerland the immediate introduction of a DAREA scheme is legally possible.

Long-term perspective

As shown in the preceding section there are several criteria describing different possible initial situations which are relevant for the choice of the IRPS most preferable in the long term. To derive sensible solutions we have to introduce a kind of ranking of these criteria. After checking different possibilities we concluded that the most relevant criteria to take account of are: “Financial needs” and “Density of road network”. The figure below shows the general influence of these two criteria on the choice of the basic form of IRPS.

In this context, “financial needs” are understood always in connection with the expansion/maintenance of the motorway network. Therefore a “yes” to this criteria is a first, but not final indication for **NET** (distance dependent network pricing). A “no” leaves the choice of the IRPS rather open.

Secondly, the density of the road network determines if network pricing could cause undesired detour traffic. Especially if tolls are applied in a congested region, and this congestion occurs not only on the motorway but also on the road network around it (for instance in a densely occupied corridor or in a large peri-urban agglomeration), a **NET** scheme involves significant risks of inducing high levels of detouring traffic to free access roads, which normally run closer to urban areas, thus strongly increasing external costs (local environmental aggressions and accidents). In such cases a distance dependent area pricing scheme – **DAREA** – is the appropriate option, although not the only solution, as preventing detour traffic can be made through other types of intervention, namely traffic engineering measures that make crossing of urban areas very inconvenient (e.g. itinerary restrictions and/or time restrictions). However, additional criteria should be considered to determine the basic form of IRPS:

Regional differences in road network: For reasons of equity between regions in the same country it may be difficult or even impossible to apply a **DAREA** scheme in a region with a dense network and **NET** in the other regions, since the citizens and companies of the former would feel negatively discriminated with respect to the rest of the country. There are possible exceptions to this rule: First, if the dense area is clearly richer than the remainder of the country the introduction of a **DAREA** scheme in this richer region and of a **NET** scheme in the rest of the country may be accepted. Second, the tariffs applied for the **DAREA** scheme could be lower than on “**NET** – roads”. Third, the revenues from the **DAREA** scheme are used for specific road infrastructure investments in the **DAREA** region (e.g. for the development of road and public transport infrastructure). In these cases a combination of **NET** and **DAREA** may be acceptable as a plausible solution.

Congestion sensibility (need to introduce management of traffic flows) and environmental concern are the other main criteria influencing the choice of the IRPS: In a European context where these two objectives are given high political and public priority and where the road network is dense, a **DAREA** scheme is the preferred approach. In this case **NET** only makes sense if detour traffic is no problem, and this will probably only be the case in sparsely populated regions. To take an example: The Rhone Valley in France is a corridor region with increasing congestion problems due to very high volumes of HGVs and car traffic. The effects of the existing network pricing on demand is on the one hand limited (with still rising congestion), on the other hand higher tariffs would cause additional detour traffic using the secondary road network. Therefore, with a **DAREA** scheme within this corridor, the detour traffic problem could be kept under control and at the same time congestion pricing could be introduced.

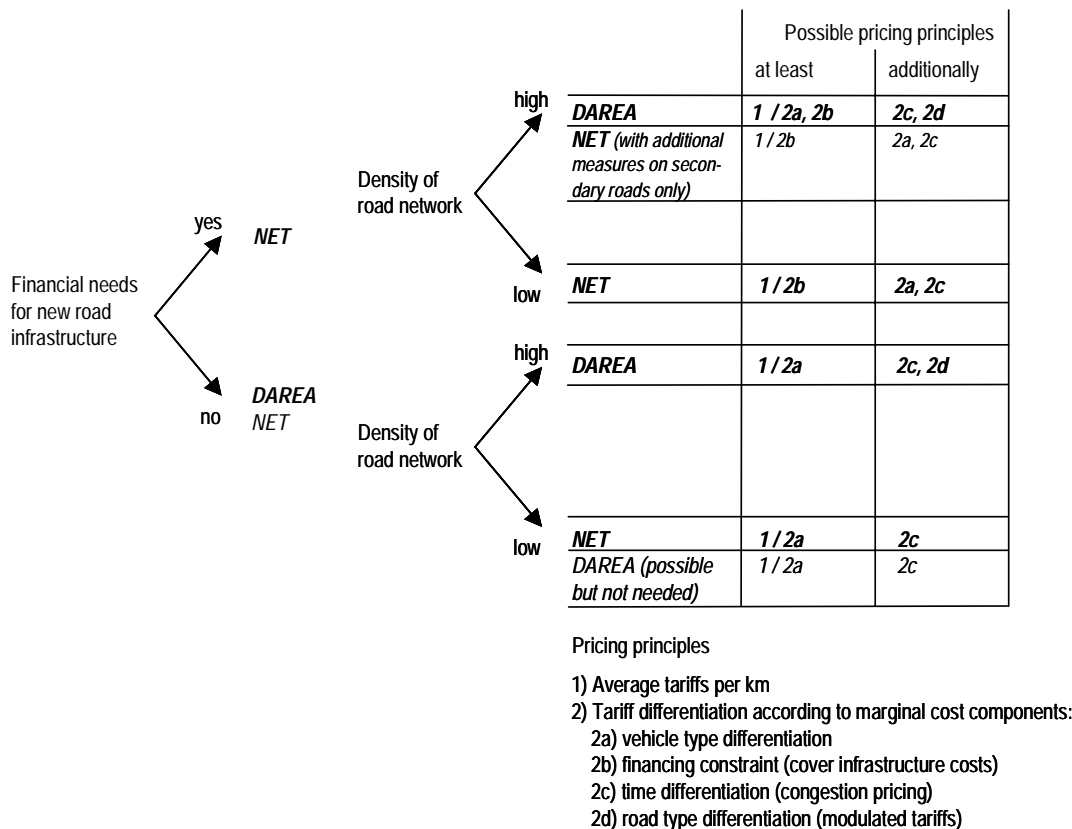


Figure 1. Decision tree to derive basic form of IRPS

A further aspect has to be considered: it concerns the pricing principle to be applied: with network pricing the freedom of choice of the pricing principle is restricted. One reason is that in most cases network pricing is linked to financial needs, meaning that it should contribute to the full or part cover of motorway infrastructure costs. With network pricing the “at least” pricing principle is therefore bound at a financing constraint. In addition, it is conceivable that some marginal cost pricing principles are taken into consideration also with network pricing, especially time differentiated tariffs (congestion pricing) and differentiations according to vehicle types. The extent to which such differentiated tariffs are possible also depends on the institutional solution.

With a DAREA scheme the use of a modulated km-based tariff for the tolling should be considered, according to the hierarchy of roads, as this may help to achieve a desired balance of traffic volumes among road types. It makes sense to differentiate between 3 to 4 types of roads, but a general correspondence between road type and price level does not seem possible, since different approaches to price setting may well lead to radically different correspondences:

- If quality of service or average cost pricing principles prevail, motorways will be more expensive as the service they provide is better and their (per vehicle) construction and maintenance costs are higher than for free access roads, except for those with very low traffic volumes;

- If internalisation or marginal cost pricing principles prevail, local roads will be more expensive, as they lead traffic closer to urban (often residential) areas, where the nuisances of traffic are particularly felt;

In reality, there will be a mix of policy goals which can be pursued through selection of these prices, but here like in so many other markets, adequate segmentation is a powerful instrument which should not be discarded.

5. Perspectives for Interoperability

As shown above, current developments clearly indicate slow motion towards generalisation of HGV tolling in EU countries, as well as a clearly dominant domestic perspective in the framing of the decisions in this respect. As a consequence, not only several types of technological solutions are in operation, but the countries approaching implementation are opting for yet different solutions. So, interoperability does not seem to be anywhere in the agenda, despite the political efforts and the investment made by the European Commission, namely in research and development programmes. This section tries to identify the main pro and con issues in this argument, and point out a likely evolution path.

This lower role of interoperability in national discussions about tolling HGV's is possibly because the political stakes are so high in this discussion. The sensitivity of the various stakeholders at national level is such that compromises must be made, and introducing interoperability (with whom, since the "others" are all so diverse?) would increase the complexity of the negotiation process possibly beyond the point of possible agreement. Moreover, the percentage of HGV's of national fleets that frequently operate abroad is relatively large in only some EU member countries, thus making the issue really relevant only there.

When a HGV goes abroad to a country where road tolls are applied, there are some gains if an EFC system is available and may be used (interoperability): no stopping for payment, no need to use cash or keep tolling receipts, even if credit cards or petrol cards might be used. But the cost of not having this interoperability is only significant if such truck makes foreign trips frequently and there are large numbers of tolling stations on its route. Of course, from a symbolic point of view, interoperability is also important to help build the image of the European single market.

In the end, each country having decided to introduce road charges for (at least) HGV's has done so in a rather complex problem setting, considering the financial needs for road network maintenance (sometimes also expansion) as well as the current and likely future situation of road traffic congestion.

But if one tries to understand the reasons behind the different technological options recently made by Austria and by Germany – although both countries opted for a NET basic form without toll plazas as it is applied to an existing motorway network with many entry and exit nodes – other factors have to be considered: Austria opted for DSRC, favouring low implementation costs and time, and short-term interoperability with other countries who already had EFC systems in operation, whereas Germany opted for GNSS/GSM, possibly favouring a pole position for its industry in the race towards applications for the GALILEO

satellite system, as well as easier future evolution to a DAREA form (at least in some denser regions), and giving less weight to low implementation costs and time.

One first level of interoperability is now technologically closer for the existing tolling systems based on toll plazas, with the adoption of the European (CEN) standard for electronic fee collection based on DSRC. This concerns the tolled motorways in Portugal, Spain, France and Italy. There may be some reconversion costs, but the main barriers certainly are of institutional and financial transaction nature. Switzerland and, more recently, Austria, also opted for DSRC based systems, although without recurring to identification and charging at toll plazas (which do not exist in these countries). Since these two systems have a different basic form (DAREA in Switzerland and NET in Austria) but a commonality of the technological base, vehicles equipped for the Swiss system will be able to use the Austrian electronic fee collection but not vice-versa (a connection to the tachograph would be needed). Motorway operations are progressively evolving from “closed systems”, where all revenue-relevant transactions are held within their borders, to sub-systems in a network, in which they collect (or give orders to collect) revenue that has to be transferred to others, and vice-versa. This involves setting up more sophisticated information and control systems, and probably solutions involving some kind of cross-operator clearing house will arise, all of which has non-negligible installation and operation costs for the motorway company.

When moving from a DSRC based system to other systems, interoperability is lost unless additional OBU's are installed and contracts are signed. There is space on the windshield for such additional items, but it is unlikely that drivers accept them easily, at least beyond the second.

This will create pressure from international hauliers on the European Commission and on national governments, but the issue of cross-Europe interoperability will not be seriously tackled until after the fact of tolling HGV's is well digested politically in all newcomer countries. Then (and only then), it will be hailed as an important instrument to completion of the European single market.

But by then, two evolutions will probably have taken place:

- on the demand side, several regions where NET tolling has been introduced in spite of having dense road networks, will be experiencing bad traffic detour problems and corresponding protest from affected citizens;
- on the supply side, the GALILEO satellite system will be in place and in need of customers. EU Member countries, in taking their decision to go ahead with the development of the system on March 26, 2002, have been clear in stating that public funding for the system should not exceed 1/3 of the costs, and all experts point out that transport applications are vital for generation of revenue from the private side. Identically, the third generation of cellular phones (UMTS) will also be in dire need of business, given the high costs of infrastructure development and (in some countries) of license acquisition. For both these systems, harmonisation across all Europe is no longer in question, cross-border billing is no problem, and their suppliers will be very much willing to come to the rescue of the so much requested interoperability.

When these conditions are satisfied (possibly between 2008 and 2010), a path of convergence should be established so that:

- progressively, all schemes based on toll plazas will be applied only to non equipped vehicles;
- NET and DAREA schemes can co-exist in different regions of the same country, without need for two on-board units (but possibly accepting them for some years);
- rather quickly all new vehicles will be equipped with GNSS and UTMS capabilities (justified for safety and security reasons and navigation help, as well as for charging), thus discarding in a relatively short time span the problem of non equipped vehicles;

Since there will still be different objectives for the existence of road tolls for HGV, adoption of compatible technologies will most likely be done while keeping different pricing regimes. On the institutional dimension, different solutions will be in existence for the financing of the road construction and maintenance, but it is likely that simplicity of international procedures will induce high degree of similarity for the institutional choices regarding the charging operations: prevalence of a high number of transactions of relatively low unit value, and need to periodically bill very large number of clients suggest that cellular phone companies may have a in-built advantage in winning the race for this business.

6. Conclusions

The completion of national tests has allowed to identify “irreversible” national decisions concerning short-term implementation/further development of electronic IRPS.

In the absence of meaningful changes to present national motor fuel taxation schemes under consideration at national level, a *business as usual scenario* best describes the context in which the level and structure of road infrastructure charges, for both HGV's and cars, will continue to be set.

With conditions in place to charge HGV's as a function of mileage performed on both Austrian motorways and the whole Swiss road network, the Alps will be the test field for “second-generation” national approaches to make ‘road users and polluters pay’ in Europe and for using resulting revenue to expand capacity and standards of transport networks. Then, progressively, other countries will start introducing HGV tolling in their practice, largely based on domestic considerations, but letting this become established practice. Interoperability will really not be in the agenda in this period, except among countries that introduced tolling in the first generation (which form a continuous geographic space).

Only later, when systems go through their adolescence and start feeling corresponding strains, will the pressure for more flexible charging systems and interoperability rise. There will be support for this pressure from the supply side, with the GNSS / Galileo and UTMS suppliers invoking how much helpful they could be to solve all those problems. The conclusion is, there will be solutions available to provide full interoperability, but conditions to achieve it must be ripe both from the demand and from the supply side.

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