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Technology for pricing policy - experiences with current schemes -

Report

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Summary

There are presently several transport pricing schemes existing in Europe and beyond. They range from the basic access fee for the city centre of London to the country-wide kilometre charge for lorries in Switzerland.

While each technology has its disadvantages at least three different technologies have proven their worth as road pricing technologies. These are DSRC, automatic number plate recognition and GPS.

Differentiation of charges according to environmental performance, such as emission standards, is practicable and is already used in Germany and Switzerland.

For lorries there are several options available for detailed differentiation and even kilometer charges, but for passenger cars anything resembling a kilometer charge has been limited to cash tolling, although current trials with GPS indicate that in principle it is possible to have a similar system.

A nationwide scheme including all vehicle types on all road networks will, even for a small country like the Netherlands, be of a scale larger than anything seen so far which has been limited to a small part of the national traffic: the city centre of London, lorries but not passenger cars on German motorways, etc. A full-scale national scheme may require more than current technology can offer or be very expensive.

Table 1 and Table 2 below summarize the main findings for the schemes surveyed.

Table 1 Overview of road charging systems

		London	Germany	Switzerland	Austria
Operational since		2003	2005	2001	2004
Type of charge		Access fee	Kilometre charge	Kilometre charge	Kilometre charge
Which vehicles charged?		All	HDV > 12t	HDV > 3.5t	HDV > 3.5t
Charges apply to		Inner London	All federal motorways	Everywhere	All motorways and expressways
Traffic volume involved		250 000 vehicles/day	62 million vehiclekm/day	Ca. 6 million vehiclekm/day	Ca. 9 million vehiclekm/day
Main Techno-logy	Charging	Declared by user	VPS	DSRC+ tachograph	DSRC
	Detecting offenders	ANPR	DSRC, Imaging, ANPR	DSRC, Imaging, ANPR	ANPR?
Differentiation used		None[1]	- EURO-norm - Axles	- Emissions - Max weight	- Axles
Charge level (2005)		£5 per day on weekdays 07.00 - 18.30	0.09 - 0.14 €/km	0.25 - 0.35 €/km for a 30t lorry[2]	0.13 - 0.27 €/km
Penalty level*		£80 (ca. € 65)	Min. € 45	Min. € 65	€ 220
Payment		Automatic=no, but monthly or annual licence can be purchased	- Automatic - Pre-Pay - Post-pay	Automatic but requires monthly sending of data	- Automatic - Pre-Pay - Post-Pay
Estimated annual operating costs of the system (million Euro)		Ca. 100	Ca. 600	Ca. 30-50	Ca. 75
Estimated annual operating costs per vehicle		-	Ca. € 400	Ca. € 200-300	Ca. € 370
Estimated production cost per OBU		N/A	€ 300	€ 800	Ca. € 20-50
Annual revenue		62M -200M	3000M	780M	600M

ANPR: Automatic Number Plate Recognition; DSRC: Dedicated Short Range Communication; VPS: Vehicle Positioning System (GPS in this case). HDV: Heavy Duty Vehicle (lorries); OBU: On-Board Unit.

Main technology - charging is the technology used to determine when, where and how much to charge users. Note on payment: for the three systems of kilometre charging, all users without on-board units must pay manually for every trip.

* Penalty levels given here are indicative and may vary according to the situation. All cost and revenue figures are rough estimations and should only be compared with great caution.

[1] However, certain vehicles are exempt, and local residents are exempt or entitled to large discounts.

[2] Rates are proportional to maximum permissible weight, so a 15t lorry is charged half of the above amount.

Table 2 Most attractive technology options for road pricing

	Main technology choices	Main advantages	Main disadvantages
Kilometre charge	VPS	Very suitable to charge according to location. No gantries needed.	Currently too unreliable for city use*. Expensive.
	DSRC+ tachograph	Cheap, few gantries needed.	Location-specific charging complicated.
	DSRC	Cheap.	Requires extensive gantry network.
Cordon/passage charge	DSRC	On-board unit (OBU) can communicate costs to user allowing a more detailed charging.	-
	ANPR	No need for OBU; less on-street hardware.	-

*This applies to the GPS system. The future Galileo system is expected to perform better.

1 Introduction

1.1 Purpose of this paper

Pricing policy is a subject of much attention at EU level, national level, and even local level. As the notion of the ‘Polluter pays’ principle, is becoming generally accepted, road pricing emerges as suitable means to apply this principle to road transport. Road pricing offers possibilities of charging road users quite accurately according to how much pollution they cause or, as is more common practise at the present, according to how much damage they cause on infrastructure. Even in the latter case, there are clear environmental benefits as the charging gives the user incentive to avoid inefficient or unnecessary transport. The theoretical merits of road pricing have received a great deal of attention in other works, but is not the focus of this paper.

This paper gives an overview of the technology used for currently existing schemes for pricing policy, and key features of these schemes. The focus is on technical aspects, the possibilities these offer and the limitations. The insights in presently working schemes for road pricing give policy makers interested in road pricing a clear indication of what is currently practicable and provides some lessons for which options are not yet practicable.

2 Introduction to differentiation options

Differentiation of charges means applying different charges in different situations or for different users. The major advantage of using differentiated charges is that transport users can be brought to pay a charge that quite accurately reflects the external costs caused by the transport activity.

Common to all forms of differentiation is that it makes the system more complicated and makes the charging scheme more difficult to comprehend - one factor of the common public opposition to road charging schemes. This is particularly a concern in the process of charging users the cost of use. Users must clearly understand how much they need to pay. Fitting cars with in-car displays for trip charges, such as used in trials in Copenhagen could help make costs more transparent.

The degree of possible differentiation according to vehicle characteristics, such as EURO standards, depends on either what information is asked from the user upon registering for the system or what is available from the national vehicle register. In the case of the Netherlands, the national vehicle registry (RDW) has since 1998 also registered EURO-class information.

Differentiation according to EURO norms requires that there is some centralised database with information on each vehicle's characteristics. That makes differentiation according to EURO norm technically possible with all forms of charging except cash tolling. However, the ease of including that extra information will depend on the particular case.

Differentiation according to time is possible in all cases, although may be difficult for paper licensing. In all cases the practicability depends on the technology used for charging.

3 Available technologies for road pricing

Road pricing can take a variety of forms, depending mainly on the technology used. In this chapter the main technologies available for road pricing are described.

Broadly, the technology used (or the combination of technologies) should be able to perform the following tasks:

- Detecting vehicles.
- Determining the charge to apply when charges are differentiated.
- Detecting offenders.

The capabilities of each technology on these points are explained in each of the sections below.

3.1 Cash tolling

Although best known for motorways and major infrastructure (bridges and tunnels), cash tolling is possible for cordon charging schemes. It requires manned or automatic collection facilities at each entry point. It may be an appropriate
approach for small areas or those that are lightly trafficked, but has adverse implications for land use because of the need for toll plazas and staffing. It is more likely that a cash option might be provided in association with another parallel charging mechanism such as DSRC or VPS. A drawback of cash tolling is the inconvenience and delay associated with the need for vehicles to stop and pay.

Cash tolling is widely used with many major bridges, tunnels and motorways in certain countries (e.g. Italy and France).

Figure 1 A toll plaza in the UK

3.2 Paper licences

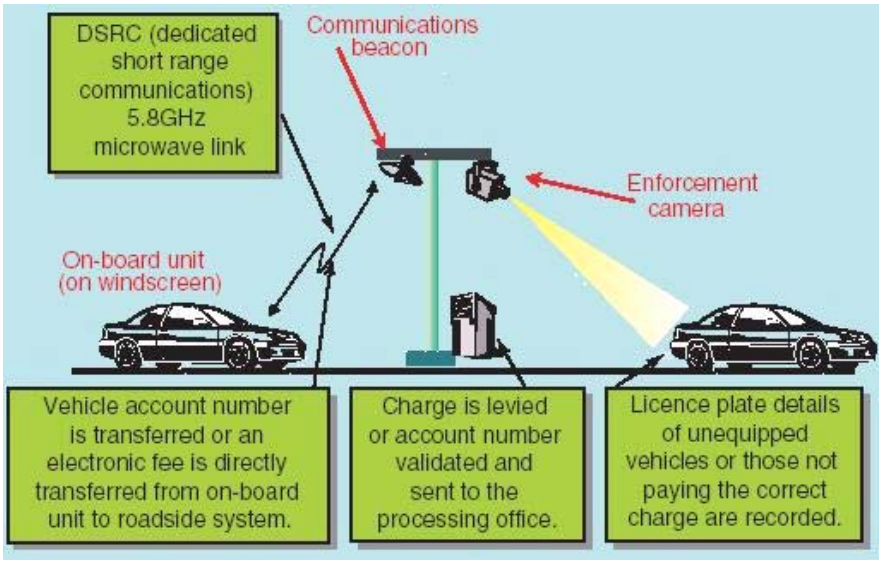
Paper licenses can be issued to provide authorisation either to be within a charged area (area licensing) or to enter one (entry permit). A scheme based on paper licences can be set up relatively quickly and might be an attractive option for an initial small scheme implementation.

Paper licences have significant disadvantages in terms of enforceability. Enforcement checks by patrols on parked vehicles in an area licensing scheme are labour intensive but relatively straightforward. However, enforcement checks on moving vehicles (although carried out in the past in Singapore) are much more difficult to accomplish, giving greater opportunity for evasion, through forgery, for example. Moving from paper licences to electronic approaches could also create some transitional problems.

3.3 Dedicated short-range communications (DSRC)

DSRC is based on communications (usually microwave) between an on-board transponder and roadside equipment installed at the charge point. This triggers a charge transaction, which is either recorded in the on-board unit or in an off-vehicle central accounting system. DSRC based charging is becoming increasingly common around the world, both for urban and inter-urban charging. It is often chosen because of its simplicity and tried and tested concept.

Figure 2 DSRC technology



Source: http://www.raeng.org.uk/news/publications/ingenia/issue14/Ingenia%2014%20Hills.pdf

There are also health and safety issues for any system that uses an in-vehicle unit. In order to ensure minimal driver interaction, information on charges made and remaining credit will be useful, but must not be displayed in a way that distracts a driver from the road. Also important in this respect are more 'basic'

safety measures to ensure that any in-vehicle unit does not impede the drivers view, and does not become detached and loose inside the vehicle in the case of an impact (http://www.europrice-network.org/pdfs/gp3.pdf).

All parts of the charging equipment will have a determined lifecycle and require replacing. It is assumed that DSRC equipment has a lifecycle of 5 years. In contrast, ANPR (see later) has less on-street hardware and no in-vehicle units to replace, and VPS charging (see later) does not require beacons; this suggests that the regular replacement costs may be less for these latter two.

Disadvantage: road-side infrastructure (gantries) is needed at every charging and enforcement point. Gantries can cause significant levels of visual intrusion, particularly in built-up areas.

Used in: Austria, Trondheim, Oslo, Rome, Helsinki, and in Singapore since 1998.

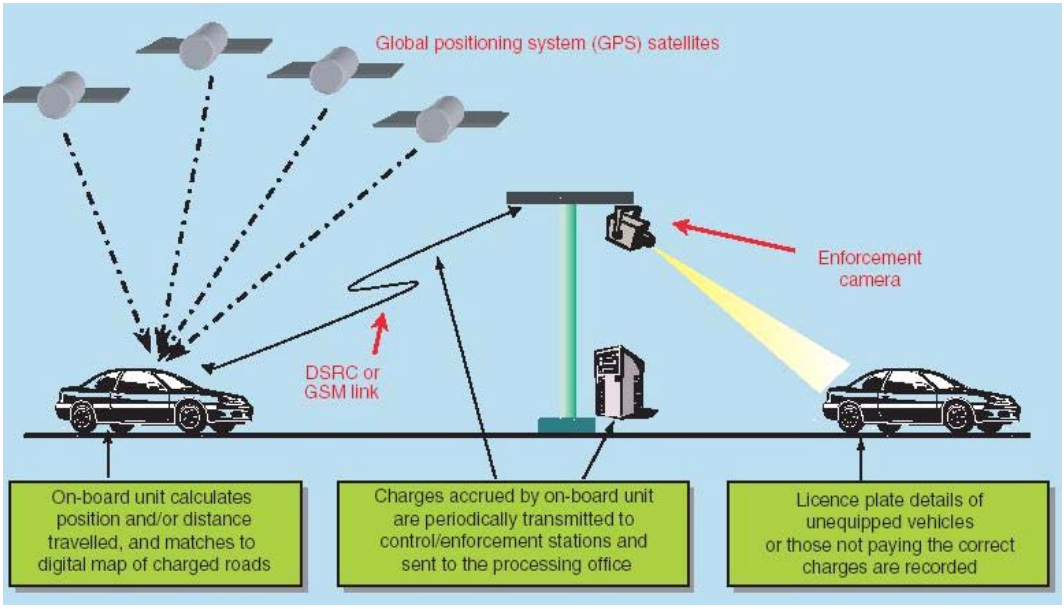
Figure 3 Toll Gantry in Austria

Picture Source:
http://www.asfinag.at/maut/mautordnung/files/en/Mautordnung_Version%207%20Endfassung_engl_191204.pdf

3.4 Vehicle positioning systems (VPS) and GPS

VPS are based on a capability of the vehicle to locate its own position and to compare this with stored details of the charging scheme for the purpose of self-charging. This is usually based on use of satellite-based positioning systems such as the Global Positioning System (GPS) or, in the future, Galileo. The on-board equipment communicates charges (for example through GSM) to a central system either for billing purposes or to communicate logged charges paid on-board (e.g. through a stored value or smart card). Such a charging mechanism can be highly flexible, using VPS to mimic a cordon or zonal scheme, for example, but a satisfying solution to enforcement of such a complicated scheme remains to be found.

Figure 4 VPS technology



Source: http://www.raeng.org.uk/news/publications/ingenia/issue14/Ingenia%2014%20Hills.pdf.

While allowing for great flexibility, VPS based systems have in most cases turned out to have prohibitive costs. While the simplest OBU based on DSRC technology costs at most € 20,00 a GPS based OBU may cost in the range of 150-800 Euro, according to a British feasibility study (DfT, 2004b). This is particularly relevant for road charging systems involving passenger cars, as these are many in number. Per-kilometer expenses for the hardware will here be much higher than for lorries which are relatively few in number but are much more intensively used.

A limitation of GPS is that it is owned and controlled by the United States. The US reserves the right to limit the signal strength or accuracy of the GPS systems, or even to shut down GPS completely so that non-military users cannot use it in time of conflict. However, as we write a European counterpart to GPS called Galileo is being implemented and is sought to replace GPS. GPS-based positioning systems are presently not reliable because of the intrinsic positioning error and the poor availability of the system discourages widespread application. This is mainly a problem in cities where signal loss often occurs due to shielding by tall buildings or in parking cellars. Problems also arise along the cordon where correct position determination is fundamental: the enforcement procedure cannot accept position errors. This application requires greater positioning precision, better availability and reliability than GPS currently offers, and this would be feasible with Galileo (http://www.europrice-network.org/pdfs/gp3.pdf).

In its 2004 study of the feasibility of national road pricing, the UK Department for transport concludes:

> 'national road pricing is not currently technologically feasible in terms of practicality, functionality and cost. But it is becoming so. Our best estimate is that it will be available within the next 10 to 15 years. This view is based on market-led development of satellite navigation and the deployment over the coming years of the Galileo satellites leading to more accurate and reliable equipment.' (DfT, 2004a)

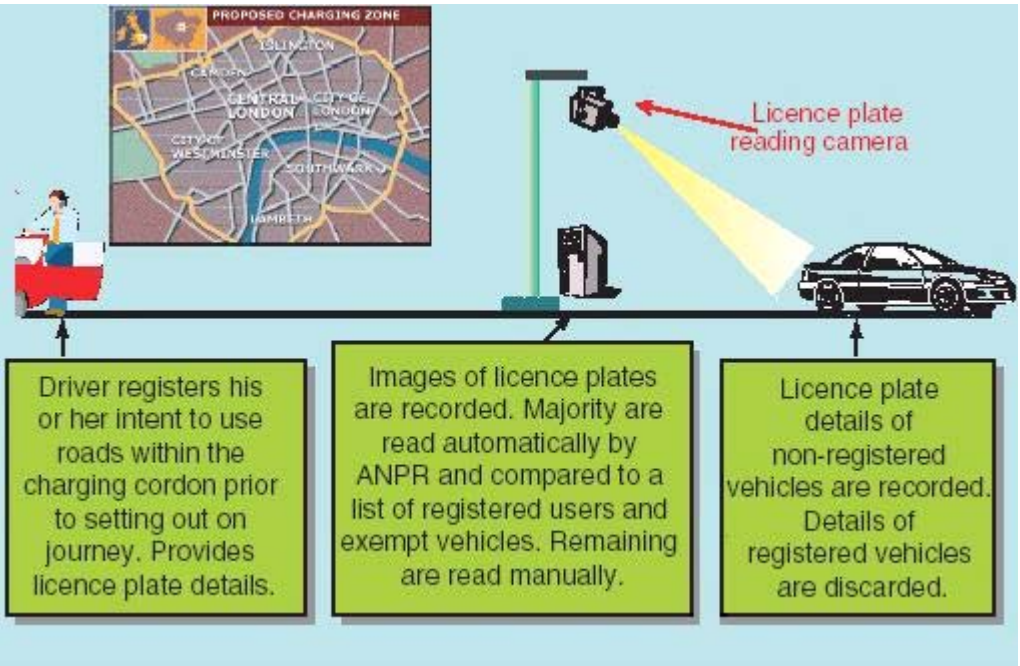
VPS is used in Germany (*Maut*), and in trials in Copenhagen, Gothenburg and Bristol.

3.5 Automatic number plate recognition (ANPR)

ANPR is perhaps best known for its use in London, but is also very widely used as a tool for detecting and identifying offenders in many other situations including speeding.

With ANPR, users are required to pay for a licence in advance and register their vehicle registration number in a database for use of the road network in the charged area. ANPR equipment at entry points and other locations then checks the registration number of each vehicle entering the charged area and if it is not recorded in the database as having paid the appropriate licence fee an image is retained for subsequent follow-up action. Pictures of cars determined to be in compliance are typically deleted immediately. In some cases, such as in London, the police can request specific information but cannot browse the whole database at will.

Figure 5 ANPR technology



Source: http://www.raeng.org.uk/news/publications/ingenia/issue14/Ingenia%2014%20Hills.pdf.

Photographing cars has lead to some concerns over privacy. This includes concern over the information being used for different purposes than intended and concern of being photographed with a passenger who was not supposed to be there (the secret mistress problem) or at a place or time where one was not supposed to be. A partial solution to this is seen in Rome, where infrared lamps render window panes opaque on ANPR images.

An important structural limitation of the electronic gate system in the ANPR system is the high rate (often about 5-25%) of failure to read correctly a number plate of a vehicle entering the zone. Visual identification is particularly difficult under conditions of poor visibility due to bad weather or snow and dirt that obscures the number plates. However, under proper circumstances a modern ANPR system has a recognition time of less than two seconds and is therefore able to record up to 1,800 vehicles/h per lane which makes it suitable for even dense city traffic.

An important advantage of ANPR is that it relatively easily accommodates occasional users since there is no need for installing any on-board equipment.

As ANPR can be set up practically anywhere its uses need not be confined to a simple one-cordon charging system. A finer network of ANPR stations could be used to create a more detailed network of zones with different charges, or it could be used to enforce charging on a specific trajectory.

3.6 DSRC + tachograph

Switzerland has adopted a scheme combining two technologies, connecting an on-board DSRC device to the tachograph[3] installed in the lorry in order to record the exact number of kilometres driven. The system is described later (see case: Switzerland).

[3] A device recording the speed driven at a given time. From this the distance travelled is calculated.

4 Payment methods

4.1 General requirements

Where older tolling systems involved a substantial amount of hassle concerning payment, most modern systems have options for payment that does not involve any delays for the user and can be largely automated. Forms of automated payment are ideal for the regular user, but for the occasional user it is often preferable to be able to pay in cash.

4.2 Manual payment

Manual payment is the old-fashioned way of paying the toll, either at a ticket-machine, or from a person. While it takes more time, it requires little or no knowledge of the system, is simple to perform and transparent. It is therefore more suitable to occasional users than forms of automatic payment and it is therefore practically always offered as an alternative to automatic payment.

4.3 Automatic payment

Automatic payment means that users can set up an account or similar from which the fees will be automatically deducted without any need for the user to provide information on each trip. The two options here are Pre-Pay and Post-Pay.

Pre-Pay
With pre-pay, the user pays an initial sum of money from which all subsequent charges will be deducted. It is equivalent to the pre-pay cards known from mobile telephones.

Post-Pay
With post-pay, the user provides her bank account information, and all charges will at regular intervals be automatically deducted from the account.

5 Case 1 - the London congestion charge

5.1 Short description

All drivers entering the inner city of London have to pay an entry fee of £ 5,00.

5.2 Scale of the system

The congestion charging zone covers an area of 21 km^2; representing 1.3% of the total 1,579 km^2 of Greater London; there are 174 entry and exit boundary points around zone.

Roughly 250,000 vehicles make 450,000 movements into the charging zone during the period 07.00 - 18.30 with 40,000 vehicles an hour driving into the congestion charging zone during the morning peak (07.00 - 10.00) - the equivalent of 25 busy motorway lanes.

Source: Transport for London fact sheet:
http://www.tfl.gov.uk/tfl/cc_fact_sheet_key_numbers.shtml

5.3 Technical and organizational characteristics

While users have to pay the fees manually, the advantage of the system lies in the automatic enforcement using the ANPR technology previously described.

The ANPR cameras used in London have an 90% accuracy rates and can check up to 3,600 number plates an hour on cars travelling in excess of 100 mph, so users can't avoid the toll by speeding.

203 sets of congestion charging cameras on the boundary of the charging zone and within use ANPR technology to record the number plates of vehicles in the charging zone.

Handling the charges is in itself a large operation: Charge payments average in the region of 550,000 payments per week. A call centre currently handles around 66,000 calls per week through customer service representatives, of which approximately 65 percent relate to payments and 35 percent to enquiries. Around 35,000 calls a week are handled automatically through Interactive Voice Response (IVR).

5.4 Charging and payment

There are no tollbooths or barriers around the congestion charging zone and no physical tickets or licences. Instead, drivers or vehicle operators pay to register their vehicle registration number on a database for journeys within the charging zone. Receipts (or receipt numbers) are available through all payment channels as proof of charge payment.

Vehicles are charged £ 5,- for entering during the congestion operating hours: 07.00 - 18.30 Monday to Friday, excluding Public Holidays. Traffic signs make it very clear exactly where the charging zone is.

Figure 6 Signs indicating the entry of the charging zon in London city centre

Exempt vehicles are: electric or alternative fuel vehicles, taxis, and vehicles with more than nine seats.

Local residents are entitled to a 90% discount.

Frequent users can purchase ‘tickets’ valid for longer periods of time, such as a month.

Various methods of payment are offered: retail outlets, internet, SMS, telephone, post.

5.5 Enforcement

Fixed and mobile cameras capture images of vehicles entering, driving within or leaving the congestion charging zone, and the registration number plates are interpreted by Automatic Number Plate Recognition (ANPR) computer systems.

Once a registration number captured by the cameras has been matched, showing that the appropriate charge for the vehicle has been paid or the vehicle is
exempt or 100% discounted, the images of the vehicle and related details are automatically deleted from the database in line with data protection legislation.
The day following capture, all images of vehicles for which no charge has been paid are manually checked against the vehicle make and model details returned by the DVLA (Driver and Vehicle Licensing Agency) before any penalty charge notice is issued.

If no record of payment has been received by midnight, an £ 80,- penalty will be sent to registered vehicle keeper. Persistent evaders are dealt with by clamping of vehicles.

5.6 Costs and revenues

Costs

In its first operating year, the expenditures amounted to £ 122.9 million, nearly entirely expenditures under the category ‘toll facilities’ (TfL, 2004).

The initially expected total start-up and operating costs over ten years were £ 720 million using a discount rate of 6% per year.

However, not included here is a variety of lead-in costs whilst the scheme is developed, such as public consultation, media campaigns, and legal/planning costs.

Revenues

Scheme net revenues were £ 43 million (ca. € 62 million) in the first operating year, less than the originally projected £ 130 million a year (ca. € 189 million) due to successful congestion reduction and higher than expected share of exempt and discounted vehicles. Beyond 2004, the expectations are £ 80-100 million a year (€ 116-145 million) of net revenues (ECMT, 2004).

The initially expected total discounted revenues over ten years are estimated to amount to about £ 1,500 million (ca. € 2,200 million) based on annual charging revenues of around £ 230 million (ca. € 334 million) and excluding any surplus from penalty charges. The net result is a discounted financial surplus of some £ 780 million (€ 1,126 million) over the life of the scheme, assuming an end date of February 2013. This revenue must, by law, be re-invested in London's transport infrastructure (TfL, 2005).

6 Case 2 - the Kilometre charge in Switzerland

6.1 Short description

The HVF (Heavy Vehicle Fee) was adopted in a referendum in 1998, where the Swiss people agreed to replace the flat fee for heavy vehicles by a distance related fee that finally entered into force in 2001. Note: In Switzerland the fee is also known as LSVA, *Leistungsabhängige Schwerverkehrsabgabe.*

6.2 Scale of the system

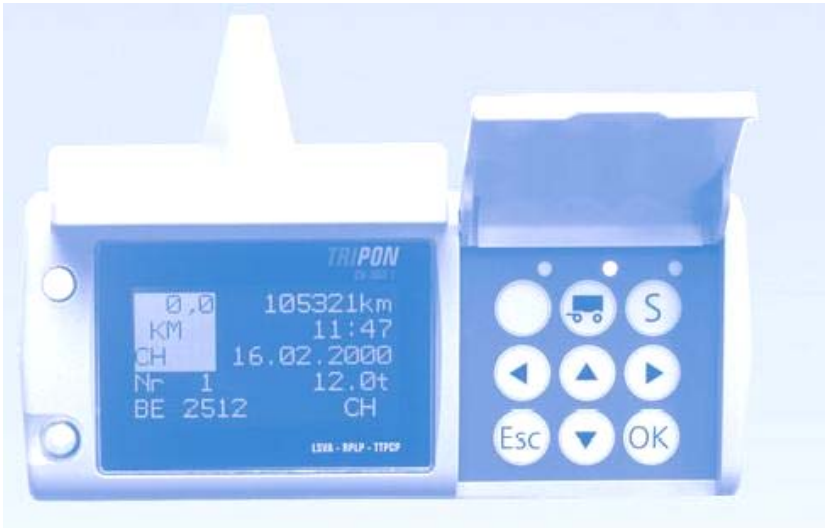
All heavy goods vehicles with a total admissible weight of more than 3.5 tons are subject to the charge, including foreign vehicles driving through or into Switzerland. Charge is applicable on the entire road network of Switzerland.

In total, the participating vehicles drive on average some 6 million vehicle-km a day.

6.3 Technical and organizational characteristics

An On-Board Unit (OBU) is fixed at the windscreen and connected with the tachograph of the lorry (the device for measuring speed and distance covered). As soon as the engine is started, the OBU starts as well and counts the electronic impulses it gets from the tachograph. In this way, it registers the kilometres driven on national territory. OBU recording on foreign territory is disabled by microwave devices placed at border crossings. Different lamps at the back of the on board unit (visible also from the outside) indicate information on the status of the OBU including proper functioning.

Figure 7 The Swiss On-Board Unit



Source: Bundesamt für Raumentwicklung (ARE), 2004
http://www.are.admin.ch/imperia/md/content/are/are2/publikationen/englisch/1.pdf

Table 3 The HVF collection system in figures

Data capture machines in use	54,000
Border crossings with appropriate equipment	82
DSRC beacons	202
Self-service machines	169
Daily Entrances/Exits with OBU in each direction	4,000
Daily Entrances/Exits without OBU in each direction	6,000
Automatic control stations	18

Source: Bundesamt für Raumentwicklung (ARE), 2004
http://www.are.admin.ch/imperia/md/content/are/are2/publikationen/englisch/1.pdf

Advantages and disadvantages

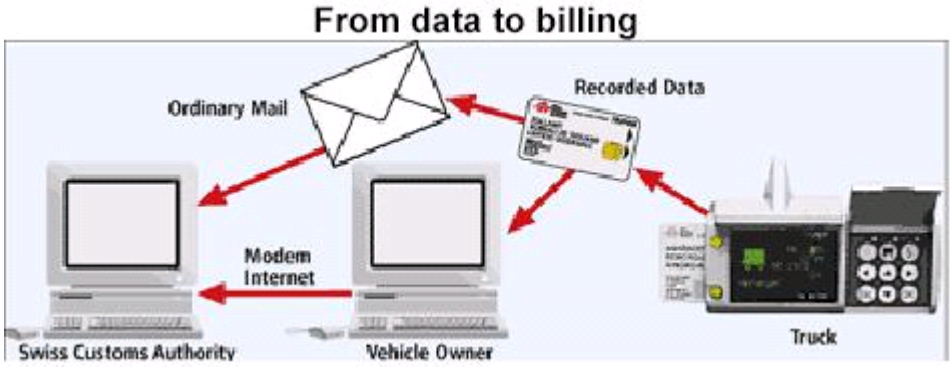
The beauty of the system is that by linking the on-board unit to the tachograph, an exact recording of kilometres driven becomes possible without the need to install DSCR gantries everywhere. However, this is also a limitation in the sense that charging differently for different locations becomes difficult. Charging only on motorways, for example, would require setting up gantries at all entries and exits of the motorway network, which would make the system more costly.
Tachographs on passenger cars may not be as compatible with the OBU's as tachographs on lorries.

6.4 Charging and payment

The admissible weight and the emission category are stored in the OBU as well as on a central system. The user can only change whether a trailer is carried or not. At the beginning of each calendar month, the data stored in the OBU has to be transmitted, physically by chip card or electronically to the Swiss Customs Authority, which is responsible for the administration and the collection of the HVF. The checked and, if necessary, corrected data then form the basis for the calculation of the fee and the billing.

While mandatory for all Swiss lorries, foreign vehicles are not required to fit an OBU and rely on manually recording km and emission data upon entering and leaving the country.

Figure 8 Overview of charging in the Swiss system



Source: Bundesamt für Raumentwicklung (ARE), 2004
http://www.are.admin.ch/imperia/md/content/are/gesamtverkehr/verkehrspolitik/27.pdf

The fee itself varies according to the following three factors:
- The kilometers driven on Swiss territory.
- The admissible weight of vehicle and trailer.
- The emissions of the vehicle (three categories).

In calculating the tonne-km, the admissible weight is used, not the actual laden weight.

Charge level was set to match the external costs of air pollution, noise and accidents, calculated to be some € 750 million in 1993, which corresponds to 1.6 cents per tonne-km. In negotiation with the EU, Switzerland finally agreed to introduce the new fee in several steps and in parallel with the increase of the weight limit:

January 1st 2001: Introduction of the HVF at a rate of 1.0 ct/tkm (CHF 0.0168/tkm). Simultaneously increase of the weight limit from 28 to 34 tons.

May 1st, 2005: Increase of the rate from 1.0 to 1.6 €ct/tkm and of the weight limit from 34 to 40 tons.

After determining the tonne-km charge, a charge factor depending on emissions is applied.

Table 4 Emission differentation categories in the Swiss heavy vehicle fee

	Corresponds to:	Charge factor
Emission class one	Euro 0/1	1.15
Emission class two	Euro 2	1
Emission class three	Euro 3/4	0.85

Source: Bundesamt für Raumentwicklung (ARE), 2004
http://www.are.admin.ch/imperia/md/content/are/gesamtverkehr/verkehrspolitik/21.pdf

The fee in 2005 is now about 8 times higher than the flat fee used in 1999, and has increased costs for transporters by about 18%. However, this is roughly equal to their gains from relaxing the weight limit (Balmer, 2003).

6.5 Enforcement

For vehicles equipped with an OBU, the OBU is able to communicate its proper functioning with a light that is visible from outside the vehicle as well as automatically with the built-in DSRC technology. If the OBU itself is tampered with, it can detect it and stores the information in the log file. 12 control stations spread throughout the country routinely check the proper functioning of passing vehicles, communicating information on possible offenders to a central computer. Imaging technology checks that the vehicle size corresponds to the information stored in the OBU.

Vehicles not equipped with an OBU are subject to periodic checks. When leaving the country, the kilometres the users have declared can be compared with the load delivery papers to check for obvious inconsistencies. If the vehicle has passed one of the control stations equipped with ANPR, the vehicle is identified and the information on its location can be transmitted to the border control as to further support a consistency check of the declared mileage.

For intentional breaking of the rules, a fine of 5 times the regular fee is charged the offender. For unintentional offenders this is equal to 3 times the regular fee. In any case, the minimum fine is CHF 100 (ca. € 65).

6.6 Costs and revenues

Total costs for the authorities of developing and getting the system operational amounted to CHF 290 million (€ 190 million) over seven years. This breaks down into 37 million CHF (€ 24 million) for development, CHF 136 million (€ 88 million) for the on-board units (€ 800 production costs apiece), and CHF 118 million (€ 77 million) for other investments.

Continuous costs of operation, maintenance, improvements, new investments, staffing, etc. are at 4 - 7% of the revenues.

Revenues in the period 2001 - 2004 amounted to about CHF 700 million a year (€ 455 million), increasing to some CHF 1200 million (€ 780 million) a year from 2005 onwards. The revenues are mainly used for improving public transport and rail infrastructure.

7 Case 3 - the Kilometre charge in Austria

7.1 Short description

The Austrian *Maut* is a kilometre charge applying to heavy vehicles and has been in operation since January 1st 2004.

7.2 Scale of the system

All trucks over 3.5 tons have to pay kilometre fee when travelling on motorways and expressways in Austria. This translates to a number of km performed by vehicles obliged to pay toll of 3,250 million vehicle-km per year, corresponding to approximately 50 million trips per year on the entire 2,100 Km long tolled network of motorways and expressways in Austria.

7.3 Technical and organizational characteristics

Vehicles have a built in OBU (in Austria called a GO-box) that registers the charge. Every time the vehicle passes under one of the 420 toll gantries, a DSRC signal is sent to the OBU indicating the position which is subsequently used to calculate the distance travelled.

During the first weeks of the system, the activity amounted to as much as 1.6 million toll transactions daily, most of them from the more 230,000 installed GO-boxes.

7.4 Charging and payment

With Pre-Pay credit is booked onto the GO-Box. When passing underneath a toll gantry the respective amount is debited directly. With Post-Pay the vehicle owner periodically receives an invoice for the kilometers covered. Post-pay has been the preferred option since the start of the scheme.

The rates vary from € 0.13/km to more than double depending on the number of axles of the vehicle.

Table 5 Toll rates in Austria

	2 Axles	3 Axles	4 or more Axles
Toll rates (€/km)	0.13	0.18	0.273

Source: http://www.asfinag.at/

The rates above are general, but for certain passes (e.g. Brenner) and tunnels higher rates apply.

The charge level is high enough to be felt on international transport, but far from severe. For a transport from Denmark to Austrian destinations the average percentage surplus costs for general cargo will amount to approx. 4.5% (ITD, 2005).

7.5 Enforcement

The Austrian case provides us with some information on the scale of the need for enforcement. During the first two weeks of operation 1,000 - 2,000 violations were detected daily. To handle this task the authorities relies on 100 gantries equipped with ANPR for enforcement, 30 mobile units and a staff of about 100 to stop vehicles, collect substitute payment, and mete out punishment. The penalty level is about € 220.

7.6 Costs and revenues

The toll system operator EUROPPASS has a ten-year service (concession) contract from the motorway operator ASFINAG. This contract includes the design, implementation and operation of the toll system for ten years. The value of this contract is about € 750 million (Schwarz-Herda, F., 2005). Production of OBUs and DSRC gantries are also included in the contract. Information on costs for specific parts is lacking, but the OBUs are estimated to cost in the range of 20 to 50 Euro. Each communication gantry is estimated to cost about € 20,000 depending on the number of lanes, while enforcement gantries are estimated at € 40,000 to € 60,000.

The system is expected to generate some € 600 million in income a year, thereby exceeding the direct costs by a large margin.

8 Case 4 - the Kilometre charge in Germany (Maut)

8.1 Short description

The German *Maut* (toll) is a distance based toll for lorries, based on the number of kilometres travelled. After several delays, it finally became operative on January 1st 2005.

8.2 Scale of the system

Liable to pay charge are all lorries over 12 ton permissible weight (buses exempt) travelling on all federal motorways, a network approximately 12,000 km in length. 1.2 to 1.4 million vehicles are liable to pay toll, hereof nearly 0.5 million foreign ones. The mileage subject to tolls is approximately 22.7 billion vehicle-km a year (ECMT, 2004).

8.3 Technical and organizational characteristics

Automatic tracking and charging is done with a GPS On-Board-Unit (OBU) which sends the travel data through a GSM mobile unit to the company responsible for charging, Toll Collect GmbH, which subsequently charges the user for the covered distance.

Accuracy of the GPS is in this case about ten meters, which limits the applicability to motorway use. However, it will be compatible with Galileo, the European alternative to GPS, once it becomes operational.

For installing the OBU, some 1,500 automobile workshops have had to be certified.

8.4 Charging and payment

Lorries not fitted with OBU can pay manually before embarking on the trip at any of the widespread *Maut* terminals. Tickets are vehicle specific and time and place-limited.

Vehicles without OBU can pay at any of the 3,585 mautterminals which are placed at petrol stations and other sites near entries to the German motorway network. Payment can also happen via internet or telephone. Vehicles equipped with OBU's are capable of automatic payment.

The revenues from user fees are approximately equal to the infrastructure costs imposed by lorries on the federal motorways.

Table 6 *Maut* user costs (€/km) valid from January 1st 2005

Emission category	Up to 3 Axles	4 or more Axles
Euro 4/5, or equivalent	€ 0.09	€ 0.10
Euro 2/3	€ 0.11	€ 0.12
Euro 0/1	€ 0.13	€ 0.14

Source: http://www.bmvbw.de/lkw-Maut-.720.22301/.htm#4

Besides the kilometre charge itself, the introduction will entail a number of supplementary costs for the transport company in the form of an installation of an On-Board-Unit, as well as administration costs and liquidity costs. However, these extra costs to the transport operators amount to some 5% of the kilometre charge itself and are thus relatively small (ITD, 2005).

8.5 Enforcement

For vehicles with on-board units, DSRC units mounted on roadside gantries detect whether each passing vehicle has paid appropriate toll. This is combined with information obtained by imaging technology on the number of axles of the vehicle. A backup system using ANPR can check if vehicles without on-board units have paid the required tolls. Nearby mobile units can then be sent to verify the non-compliance, or the appropriate authorities can be automatically notified of the violation.

300 locations have equipment for automatic video-checks (using ANPR) of lorries to ensure compliance. On top of this comes 280 mobile units with the same function. Checks in transport operators' companies complement the enforcement.

8.6 Costs and revenues

In its first year, the *Maut* is expected to deliver a gross income to the public coffers of € 3 billion. Enforcement and operating costs are expected to amount to some € 600 million per year. We were unable to find information on the start-up costs, or the costs born by the transport operators.

9 Smaller scale schemes for transport pricing

A number of smaller scale systems exist, some fully operational, others merely pilot schemes. The table below provides an overview of a few of the larger and more well-known.

Table 7 Overview of four smaller-scale transport pricing schemes

		Trondheim	Rome	Singapore	Westerscheldetunnel
Type of scheme		Full scale	Full scale	Full scale	Full scale
Operational since		1991: simple toll cordon 1998: zone based system	2001 (simpler model running since 1989)	1998	2003
Type of charge		Zone (per passage)	Annual access permit/zone based	Zone (per passage)	Passage fare
Which vehicles charged?		All	All passenger vehicles	All	All
Charges apply to		Centre of Trondheim (weekdays 06.00-18.00)	Historical Centre (5.7 km^2) weekdays from 06.30-18.00, and on Saturday from 14.00-18.00pm	the central business districts - (07.30 to 19.00) - expressways/outer ring roads (07.30-09.30.)	The 6.6 km tunnel under the Westerschelde waters.
Main techno-logy	**Charging**	DSRC	DSRC	DSRC	Cash tolling/ DSRC
	Enforcement	ANPR?	ANPR	ANPR?	ANPR?
Differentiation used		Time of day Location Vehicle type	Location	Location Vehicle type	Vehicle type (length, height)
Charge level (2005)		€ 1-2 per zone, lorries pay 2x price	Regular Annual fee: € 321; equivalent to 12 months public transport passes.	From ca. € 1.5 (cars) to ca. € 7 (lorries)	€ 3.15 (pass. Car) - € 15.75 (large truck)

The information in this table was obtained from these sources:
Trondheim: http://www.progress-project.org/Progress/tron.html , Singapore: www.lta.gov.sg
Rome: http://www.progress-project.org/Progress/rome.html and www.sta.roma.it; Westerscheldetunnel: http://www.westerscheldetunnel.nl/index.cfm?sid=22&pid=105, and http://www.rijkswaterstaat.nl/wegen/Westerscheldetunnel.asp

10 Conclusions

There are presently several transport pricing schemes existing in Europe and beyond. They range from the basic access fee for the city centre of London to the country-wide kilometre charge for lorries in Switzerland

While each technology has its disadvantages at least three different technologies have proven their worth as road pricing technologies. These are DSRC, automatic number plate recognition and GPS.

Differentiation of charges according to environmental performance, such as emission standards, is practicable and is already used in Germany and Switzerland.

For lorries there are several options available for detailed differentiation and even kilometre charges, but for passenger cars anything resembling a kilometre charge has been limited to cash tolling, although current trials with GPS indicate that in principle it is possible to have a similar system.

A nationwide scheme including all vehicle types on all road networks will, even for a small country like the Netherlands, be of a scale larger than anything seen so far which has been limited to a small part of the national traffic: the city centre of London, lorries but not passenger cars on German motorways, etc. A full-scale national scheme may require more than current technology can offer or be very expensive.

11 References

Balmer, E., 2003
Euli Balmer
Practice and experience with implementing : transport pricing reform in heavy goods transport in Switzerland, 2003

DfT, 2004
DfT (Department for Transport)
Feasibility study of road pricing in the UK : full Report, July 2004
http://www.dft.gov.uk/stellent/groups/dft_roads/documents/divisionhomepage/029798.hcsp

DfT, 2004
DfT (Department of Transport)
Feasibility study of road pricing in the UK. Section B: Cost Model Report, July 2004
http://www.dft.gov.uk/stellent/groups/dft_roads/documents/page/dft_roads_029770.pdf

ECMT, 2004
ECMT (European Conference of Ministers of Transport)
Presentation given at the joint workshop of ECMT
London : 23 January 2004

Schwarz-Herda, F., 2005
F. (Friedrich) Schwarz-Herda
Personal communication with Friedrich Schwarz-Herda, Bundesministerium für Verkehr, Innovation und Technologie, Austria

ITD, 2005
ITD (International Transport Danmark)
New Road toll system for trucks in Austria, a customer guidance
Website of International Transport Danmark, 2005
http://www.itd.dk/Upload/Okonomi/ostrigsk-vejskat-engelsk.pdf

PROGRESS, 2004
PROGRESS
Main Project Report, Version 1.0. PROGR€SS Project 2000-CM.10390
July, 2004
http://www.progress-project.org/Progress/final_report.html

TfL, 2004
TfL (Transport for London)
Annual report 2003/2004 Statement of accounts, 2004
http://www.tfl.gov.uk/tfl/downloads/pdf/about-tfl/report-library/Statement_of_accounts_for_2004.pdf

TfL, 2005
TfL (Transport for London)
Website of Transport for London
http://www.tfl.gov.uk/pdfdocs/cc/14_social_cost_of_recommendations.pdf

12 Relevant web links

http://www.transport-pricing.net/
EU-managed programme for transport pricing. Many relevant links here

http://www.progress-project.org/
PROGR€SS is an EU project covering 8 pilot transport pricing schemes

www.cclondon.com
Official site of the congestion charge in London

http://www.bmvbw.de/Verkehr/Strasse-,1436/LKW-Maut.htm
Official site of the German LKW Maut kilometre charge (in German), 28 juli 2005

http://www.zoll.admin.ch/e/firmen/steuern/lsva/ausland.php
Official site of the Swiss Heavy Vehicle Fee (English information), 28 juli 2005

http://www.go-maut.at/go/
Official site of the Austrian Maut