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Road user charging

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Cover images (clockwise from top left)

- Dartford crossing, UK
- Congestion charge sign in London, UK
- Toll booth in Hong Kong
- Traffic jam, Bangkok, Thailand

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Terminology

Road pricing/road user charging

Road pricing, also known as road user charging describes any process that associates a cost with using a length of road, such as tolling and congestion charging. It is the levying of a fee or charge for road use that aims to use price as a means to influence a proportion of the road users to change their driving behaviour and/or travel behaviour to manage the demand for the use of road space. The charge should reflect the disbenefit caused to other users by a driver and include externalities such as congestion, air pollution and noise pollution[1].

Tolling

Tolling or toll collection are the collection of a road use fee on certain roads, bridges or tunnels where the toll is levied to recover all or part of the capital, operating and maintenance cost for the infrastructure. This means that only those drivers who use the road, bridge etc are being charged for the construction and maintenance of it rather than the tax payer as a whole. In the UK, examples include the Dartford Crossing and the M6 Toll where a vehicle is charged for passing through a specific junction or using a stretch of road. Toll rings can be found around a number of cities in Norway, where the revenue pays for new roads, new tunnels and a contribution to new public transport services. In Toronto and Melbourne tolling funds new inner city roads and bridges; and nearly all French autoroutes are paid for by tolls.

Congestion charging

A congestion charge is a variable toll fee that depends on the level of congestion and is intended to reduce peak-period traffic volumes and improve journey times by encouraging changes in travel behaviour. Charges for entering a restricted area in city centres are used to manage congestion as is the case in London and Stockholm. More sophisticated schemes like that operated in Singapore change the amount of the charge according to the degree of congestion: the average speed of taxis is measured over a number of reference roads. If the speed is above the agreed reference level it is assumed that the congestion charge is over-compensating in reducing traffic so charges are cut. If the speed falls below it is assumed that congestion is too high so the charge is increased.

Why is congestion management necessary?

Externalities of road use

The direct costs of building and maintaining roads are not the total cost of road use. Economists speak about externalities, which are costs that impact on a third party and are not paid for by the market. Examples of externalities resulting from transport are congestion, pollution and noise. There is a view that the driver should pay for the external cost they impose on others. The Department for Transport gave the following figures for car marginal external costs:

Cost type	Weighted average p/km in 2010
Congestion	13.1
Infrastructure	0.1
Accident	1.5
Local air qualitiy	0.4
Noise	0.1
Greenhouse gases	0.3
Indirect tax (fuel duty and VAT on fuel)	-3.6
Total	**11.9**

Table 1: Marginal cost resulting from road transport

Of this, the largest cost is imposed by congestion. However, the cost for congestion varies significantly from 0 p/km in quiet rural areas to £1.95/km on the most congested roads in conurbations.

Growing demand on road space

According to a survey by TomTom, four of Europe's ten most congested cities are in the UK[2]. The problem with congestion is further amplified by traffic growth which far outstrips the rate of increase in total road length. Total road traffic increased by 87% between 1980 and 2007 from 277 to 517 billion vehicle kilometres. Most of this increase accounts for car traffic. At the same time the road length increased by 16% from 340,000 kilometres to 395,000 kilometres[3].

The 2008 DfT National Transport Model forecasts that congestion will rise significantly until 2025. The model suggests that congestion across the English network as a whole will increase by about 37% between 2003 and 2025. This represents an average increase in time spent travelling of 6%. This figure varies from an extra 18% time spent travelling per kilometre in London to a 2% increase in time spent travelling in rural areas[4]. However, with high fuel prices and the recession, those forecasts might have to be revised downwards.

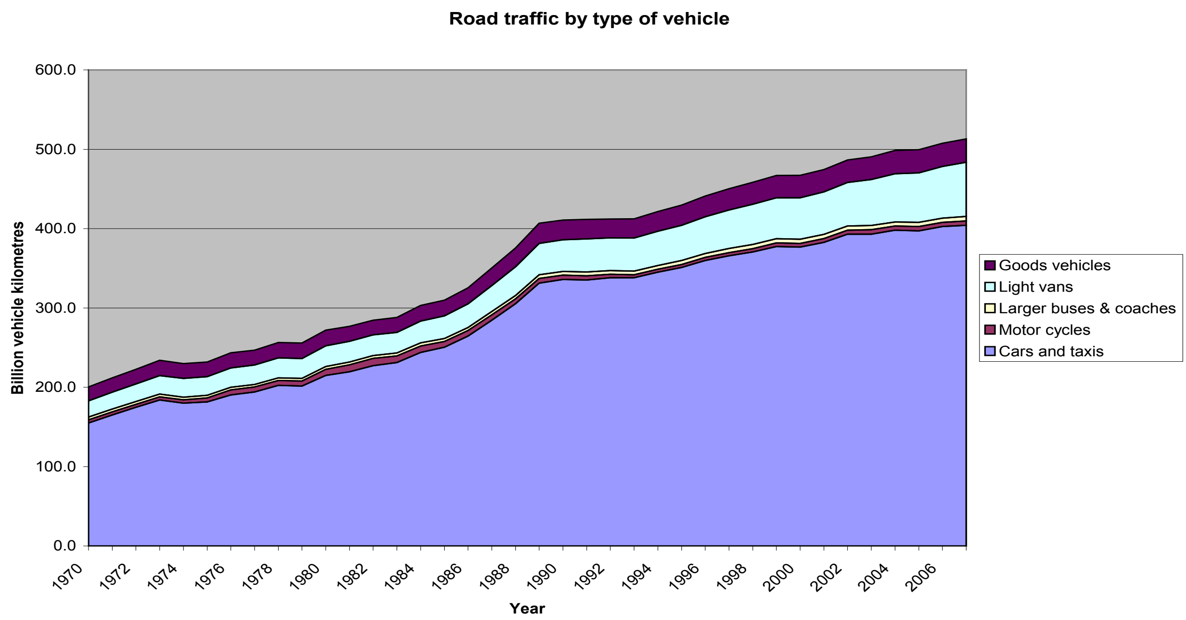

Figure 1: Traffic growth between 1980 and 2007 in the UK

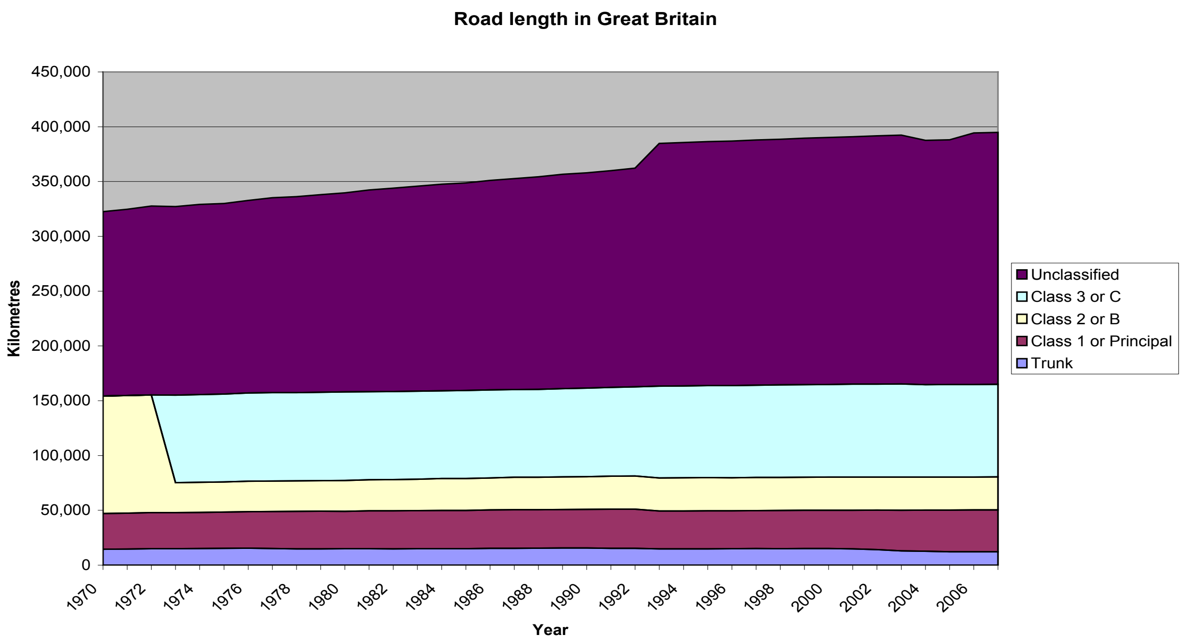

Figure 2: Growth in road length in the UK between 1980 and 2007

Year	Traffic (vehicle km)	Congestion (lost time/km)
2010	4	1
2015	17	3
2025	37	6

Table 2: Traffic forecasts for England, changes compared to 2003 [4]

Economic cost of congestion

The CBI stress that economically, the biggest issue with congestion is the lack of predictability of travel times and the reliability of the road network, which are even more important than journey-length[5]. Logistics companies are known to calculate in extra time between deliveries in order to account for unreliable networks. On days with little or no delays the drivers can return early, but they cannot deliver more goods, which does not benefit the company. Having predictable journey times would make it possible for logistics companies to optimise their delivery routes and number of trips taken. The same is true for the public travelling to work or to meetings. Arriving early is no benefit to either the company or the employee, but is required to ensure that they arrive on time.

The Eddington Transport Study[6] shows a link between gross domestic product (GDP) and demand for travel. The authors of the report estimated that eliminating existing congestion on the road network would be worth some £7-8 billion of GDP per annum and the CBI suggests the figure is closer to £12 billion.

Environmental benefits

Road transport accounts for 7% of global CO_2 emissions. In the UK, road transport accounts for about 92% of domestic transport emissions and just over half of those emissions stem from passenger cars[7,8]. As shown in Figure 3, Nitrogen Dioxide and vehicle emissions per km on motorways increase three to four times in congested areas[9].

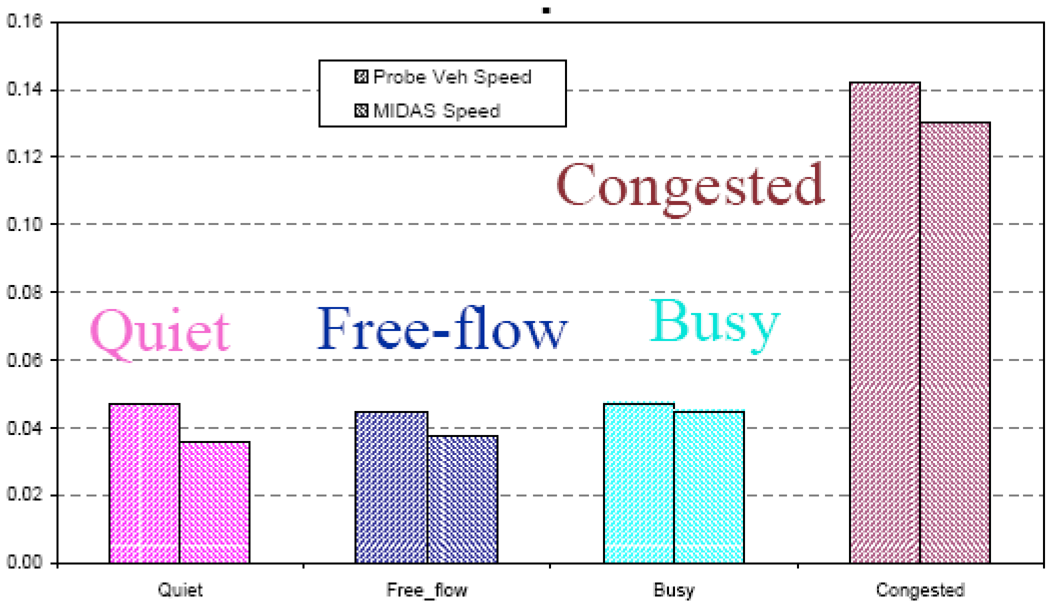

Figure 3: Levels of pollution depending on the traffic flow

Changing public behaviour

In terms of marginal cost it is often significantly less expensive to drive by car than alternatives; typical fuel costs are in the 10 to 20p per mile range, while public transport may be many times that. In general public transport will only be used if there is a barrier to car use - for example a very congested journey, sufficient to remove the convenience advantages of car travel, no parking possibility or an increased cost. The AA found that in July 2008, when fuel prices where at a peak, people started cutting back on their travel (data shown in Table 3). Road pricing should therefore induce a similar change in behaviour.

July 2008 (fuel price peak)
Due to high cost of fuel 20% cut back on general expenditure 25% travel less 32% cut back and travel less ie 57% say they travel less

Table 3: Public behaviour after fuel cost increased[10]

Raising revenue

Revenue from road user charging would allow the Government to improve road conditions and to upgrade the public transport system. The revenue could also be used to reduce the vehicle exercise duty or the fuel tax.

Additional information for the driver

By monitoring the movement of vehicles, a road pricing scheme could also generate additional information on actual traffic conditions which could be used to inform drivers about the quickest route for a journey at a given time. Drivers could be given advice on how to adjust their travel patterns and journey start times by monitoring traffic information to help them decide when their route is likely to be less congested.

Concerns about road pricing

Social inclusion

It is often claimed that people on low incomes are impacted by a road user charging scheme disproportionately. People on lower income jobs do often not have flexible working hours and hence cannot shift their travel pattern to avoid the most congested times of the day.

Expenditure[11] on transport averages 8% of gross income and vies only marginally across income groups. People with a lower disposable income tend to use buses more and those in higher incomes will use the car more. An additional charge on road use should therefore not impact to a great extend on people with lower income. However, it would mean an additional barrier to those people wanting to own a car if there are no appropriate rebates for those who cannot avoid travelling through local areas where road user charging is implemented.

Privacy and surveillance

Collecting information on the travel patterns of people can lead to allegations of privacy infringement. Key information should be transferred as aggregated data about vehicle flows, not the particular journey of an individual driver. All data need to be safely transmitted, stored and managed anonymously.

Access to businesses

One major concern over pricing is the potential long term impact on land use and business location. Driving to work is often the only option for the majority of British commuters as public transport is poor. Employers are concerned about the need to recruit and retain key staff or to do their shopping. There is a real danger that congestion pricing will result in a general dispersion of industry away from priced areas, possibly resulting in increases in travel distance and CO_2 emissions.

A study commissioned by the CBI and the Freight Transport Association found that business could benefit from congestion charging in cities so long as strict criteria are met[12]. The report highlights that overall, businesses would generate a surplus of revenue over the cost arising from congestion charging. This is largely due to the high value that businesses place on travel.

Public distrust in government

In 2008, the public voted against the implementation of a Transport Innovation Fund proposal in Manchester. The Greater Manchester Passenger Transport Authority (GMPTA) and Association of Greater Manchester Authorities (AGMA) had proposed to secure £1.5 billion from the Transport Innovation Fund (TIF) to improve public transport. The proposal also included the implementation of a congestion charge. The no-vote revealed a considerable lack of trust by the public in both local and central

Government. There was for example a widespread belief that central Government would force the local councils to raise the congestion charges once the road pricing scheme had been implemented. Another concern was a perceived lack of transparency regarding how the revenue from a road pricing scheme would be used.

Technology for road user charging

Automatic Number Plate Recognition (ANPR) system

Cameras which are situated at the entrance and exit points of a charging zone record video images of (usually) the rear of a vehicle. A computer system then processes the images to locate the number plate and determine its alphabetic and numeric characters. When paying the congestion charge before or after the journey, the driver provides the vehicle's number plate and the system automatically compares this information with the list of captured plate records derived from the recorded images. Noncompliant vehicle keepers are fined a penalty charge. The advantage of this system is that it does not require on-board equipment. The disadvantage is that it is not flexible or adaptable, it requires the driver to opt in, and accurate readings are difficult in poor weather conditions, insufficient lighting or non-standardised licence plate fonts.

Dedicated short-range communication (DSRC) system

This technology is also referred to as tag and beacon. A beacon mounted on roadside equipment communicates via a 5.8 GHz microwave signal with an in-vehicle electronic tag. When the vehicle passes a charging point, it is automatically detected, there is an exchange with the in-vehicle unit, and a number plate image is captured. The in-vehicle unit identity is then checked against a list of pre-paid travellers or approved account holders who will be sent monthly bills in the same way as for mobile telephones. If there is no match or if the electronic exchange fails for any reason the number plate image is used to contact the registered vehicle keeper to see whether a penalty notice or enforcement action might be necessary. There is work on handling payment by money held on a smart card carried inside the vehicle, as a way of extending traveller anonymity. The advantage of this system is that the charge can be automatically deducted for a registered account holder.

The system is flexible and it is relatively easy to extend or make changes to the charging tariff. However it presents a problem for occasional users who have to fit the device into their cars or the operator has to accept them using the ANPR system.

Global navigation satellite systems

This technology is also referred to as mobile positioning system (MPS). It uses a GPS or similar satellite-based positioning service and a two-way communications link. The onboard unit calculates the position of the vehicle at regular intervals to determine the total distance travelled and the roads used. If the system is a 'Thin client device' then the collection of position fixes is sent by wireless communication links to a roadside reading device that relays the information to a back office where it is matched to digital maps of charged roads and the total bill for the trip is calculated. If the on-board unit is a 'Thick client device' it holds the map and tariff data internally and carries out the journey billing calculations. The unit then sends the vehicle's bill to the roadside unit i.e. the detailed trip data does not leave the vehicle. As before there are fixed or mobile enforcement stations fitted with ANPR cameras to record licence plates to enforce the scheme. The advantages are that 'virtual' charging points can be created that do not require roadside equipment and that with an automatic system a much more detailed pricing scheme can be devised according to time of entry, distance, place of the vehicle, prevailing pollution etc.

Case studies

Over the years there have been hundreds of trials and examples of road user charging and tolling schemes. However, a number of case studies have been selected to illustrate the breadth of system types and technologies deployed. Examples range from urban congestion charging and small scale toll schemes to heavy goods vehicle charging schemes.

Congestion charge in Singapore

Singapore is often quoted as the pioneering city for successfully implemented congestion charge schemes. In the mid-1970s, Singapore was experiencing rapid economic growth along with significant increases in car ownership and car use, which was predicted to reach 10% per annum. In 1975 the Singapore government introduced the world's first area licensing scheme (ALS). The ALS initially covered the most congested road networks leading into the central business district of Singapore with 22 entry points. Each entrance was marked by an overhead gantry that marked the entry point to the ALS and its operating hours. Initially, the ALS operated between 7:30 am to 9:30 am, daily except for Sundays and public holiday, but the weekday operating period was extended until 10:15 am after the first three weeks of operation[13]. As a result of the ALS, initial peak period traffic volumes fell by 75% and traffic before 7:30 am increased by 23%. Once the scheme settled down, the deduction in traffic entering the restricted zone as approximately 44%.

Daily or monthly paper licenses had to be visibly displayed in the windscreen of cars and handlebars of motorbikes and scooters. The licenses were colour coded according to the class of vehicle. Enforcement officers performed manual compliancy checks by observing moving vehicles passing through the gantry point. Penalty charges were issued based on the license plate number without stopping vehicles to not disrupt traffic flow[14].

In the late 1980s the reduction in traffic had lessened which lead to a fundamental revision of the ALS. It was now operated not only in the morning peak hours, but also in the evening between 4:30pm and 6:30pm. As a result a reduction in traffic volume by 56% in the evening peak was achieved.

In 1994 the Singapore government started trails for an electronic road pricing scheme, which went live in 1998 after an extensive test period. A system utilising a dedicated short-range communication solution that included an in-vehicle unit with a smart card and two overhead gantries were placed at each entry point. Every time a vehicle passed through the entry point, the road-side equipment of the first gantry interrogated the in-vehicle unit (IVU), verifies its validity and deducts the entry charge from the stored value of a smart card inserted in the IVU. At the second gantry, enforcement cameras were activated if vehicles without an IVU or an insufficient balance on their smart cards were identified[15]. The level of the charge was set to try and maintain target speeds on key roads leading into the central business district. If the speeds were too low, then it was assumed that traffic volumes were too high and the charge was increased. If the speeds were too high, then the charge was decreased[16].

Congestion charge in London

In 1993 the Government Office for London (GoL) jointly with the Department for Transport (DfT) commissioned a study on congestion charging options for London[17]. The report concluded that the technology was not yet sufficiently mature to support a fully automated road user charging scheme in London. A new study into the feasibility and options of road user charging for London was initiated in 1998[18]. The study proposed to start with a small zone in the centre of London and use a camera based registration and enforcement scheme which would not require vehicles to be equipped with in-vehicle units. The system was specified and procured in just over three years and went live in 2003.

Vehicles that enter a defined area around central London, known as the London Congestion charge zone are charged a daily rate for driving and parking vehicles on public roads between 7am and 6pm Monday to Friday. Drivers entering the zone are asked to register their intent to travel before they inter the zone and to prepay the charge. The charge can be paid in shops, kiosks, on the internet, by telephone or by a short message service using mobile phones. To enforce the scheme, Transport for London operates 340 cameras across London which monitor both the exit and entry points to the charging zone. The cameras provide video-stream signals to an ANPR system which produces the evidential record of the vehicle. One camera takes a close-up image of the vehicle licence plate, with a second camera taking a wider contextual image of the vehicle to prove that it was actually inside the charge zone should that be challenged[19].

Since introducing the congestion charge scheme, traffic entering the original charging zone remains 21% lower than pre-charge levels and a 6% increase in bus passengers during charging hours was recorded[20].

Congestion charging scheme in Stockholm

In the early 1990s, Stockholm explored the possibility of introducing a toll ring around the city to finance a series of ring roads. This scheme however was cancelled in 1997 after a change in Government. In 2001 plans for a charging scheme were reviewed again and lead to the announcement of a trial for road user charging scheme in 2004. The system was allowed to run for 9 months before a local referendum would establish whether there was public support to continue and extend the scheme.

The toll system, which went live in 2006, uses infrared cameras to identify the number plates of vehicles passing in and out of the city centre. Vehicles travelling inside so-called cordons automatically pay tolls electronically using DSRC tags. Once a vehicle passes a roadside control point during designated congestion hours it is recognised by the transponder that is read by sensors. The transponder tag communicates with receivers in control points and trigger automatic payment of the charge. In addition, cars passing through the control points are photographed and the license plate numbers are used to identify those vehicles without tags and to provide evidence to support the enforcement of non-payers.

After the first full week of operation, the peak hour traffic was reduced by more than 25%. Queuing was reduced by 30-50% in morning peak and emissions measured were reduced by 14%. This settled down to 20% reduction in traffic. A referendum concluded that the public accepted the road pricing scheme.

Dartford tunnel

The Dartford Thurrock Crossing provides a fixed road link across the Thames River and is the busiest estuarial crossing in the UK with more than 140,000 daily crossings. The Crossing is comprised of two dual-lane tunnels carrying traffic to the north and a four-lane bridge carrying traffic to the south. The first tunnel was built in 1963, the second in 1980 and the bridge was opened in 1991. It is an early example for a Private Finance Initiative (PFI), transferring the existing debt from the tunnels to the private sector who would retain toll revenue to pay off the existing debt and the debt incurred by building the new bridge. As part of the agreement, the toll operator has to maintain the quality of the service and ensure adequate provision to accommodate the expected growth in traffic.

Each toll lane is equipped with an Audio video interleave (AVI) system. Some of the lanes are defined as fully automatic and drivers can either pay using a smart tag or an automatic coin machine. A transceiver is located near the exit of each automatic lane which reads the tag installed in the vehicle. Once the tag is authorized for use at the Dart Thurrock Crossing, the account will be automatically debited and the barrier will be raised allowing the vehicle to pass without stopping.

HEV toll roads

The German lorry toll (LKW Maut) was introduced in 2006 and applies to lorries with a total weight of 12 tonnes or more on all German Autobahnen (federal motorways). The charge depends on the lorry's emissions category, number of axles and the length of the journey.

The system is based on a combination of mobile telecommunications technology and satellite-based global positioning system. Most lorries are fitted with an on-board unit that transmits the lorry's position and distance travelled to the toll operator computer centre which calculates the charges. It does not require speed limits, traffic stops or restriction to prescribed lanes. Alternatively, drivers can manually log their journeys on the internet or at dedicated toll station terminals[21]. The number of low-emission lorries on German Autobahnen has significantly increased from below 1% in 2005 to almost 37% in 2008[22].

The Dutch government aims to replace road tax with a pay-per-kilometre charging scheme. Approved in 2008, the system should start charging commercial trucks for road usage by 2011, and expand to every vehicle by 2018. It will be based on a global navigation satellite system, (GNSS) anchored either on GPS or on the European Galileo satellite, which will track each vehicle's progress on a per-kilometre basis so that road usage can be charged for according to the distance travelled. The on-board equipment (OBE), required by law in all but officially exempt vehicles, will record kilometres driven as well as where and when they were travelled.

The Dutch scheme will use a thin client OBE that transmits the vehicle's base co-ordinates back to a central office where computer systems will perform all the necessary time, distance and billing calculations. A similar scheme is already running to track HGV traffic on German motorways, with another planned for France[23].

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