Moving towards Pay As You Drive

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Abstract

It was not until the 1990s that successful road user charging schemes emerged in Singapore, London and Stockholm. The excuse was that 'the technology is not yet proven', plus the difficulty of making a lucid case to politicians, businesses and individual travellers that all would benefit from the introduction of road pricing in congested cities and arterial routes. This paper shows that technology can now provide solutions to deliver innovative charging policies. We review key schemes and trials, show what can be learnt from them and how the technical innovations and the evolution in policy thinking permit schemes that make road pricing acceptable and relevant to today's congestion, energy, climate change and fiscal challenges. Moreover, these innovations enable policy makers and road operators to offer a 'new deal' for road users where ownership and fuel taxes can be replaced by more effective "pay as you drive" (PAYD) schemes based on TDP (time, distance, place) charging.

1 Introduction: technology is a policy enabler

A Global view

The development of the many policy variations for road user charging must be seen in the context of economic, social, technological and environmental policies of the last 50 years. Much has been written about the technologies underpinning road user charging but they are no more than enablers. As the underlying technologies evolve to record a vehicle's presence on a route, its distance travelled or other vehicle parameters, then so do road user charging policies. The world's first electronic toll collection (ETC) scheme (Aalesund in Norway) emerged in late 1987 from the need to lower the cost of toll collection to enable the business case for a new road. Since then we have witnessed increasing congestion in cities, shortages of public funds to provide new road infrastructure, awareness of the damage caused by emissions from road transport and the emergence of customs unions on every continent that have stimulated growth in cross-border traffic.

Other forces have accelerated the adoption of road user charging policies beyond traditional tolling; investor confidence in technology and operations means that multi-lane free flow (MLFF) tolling can be applied routinely in developed countries; the advent of fuel efficient low emission vehicles has prompted reviews in the US and Europe of tax policy that, after 75 years, is becoming increasing strained.

Also, inner city concerns about harmful vehicle emissions have ushered in low emission zones (LEZ), the largest covering 1,000 km^2 of Greater London. LEZs represent one of the fastest growing road user charging policies in Europe, applicable to small areas also, as the Commune di Milano (Italy), only 8.5km^2, highlights. There are over 50 European schemes. Technologies used include paper licenses, microwave Dedicated Short-Range Communications (DSRC) tags and Automatic Number Plate Recognition (ANPR) cameras and the associated systems and business rules that convert charging events into payments for road use.

The controversial nature of congestion charging has meant that the survival rate on the policy agenda remains low despite the fact that operationally it works very well. The widely different social and political contexts of London, Stockholm and Singapore demonstrate that congestion charging can be adapted successfully to a local context.

Truck tolling schemes aim to ensure that traffic travelling on a country's roads pays its fair share of the wear and tear of the road surface and other externalities that could not be recovered through fuel tax or an annual domestic license fee. The New Zealand policy on Road User Charging for diesel vehicles was the followed by the Swiss, Austrian, German and Czech Republic schemes.

In order to make better use of existing road space, congestion charging has emerged in cities, where road widening is not usually possible. On interurban routes, High Occupancy Vehicle (HOV) Lanes have been introduced; and where unused capacity remains, policy evolved to allow non-compliant vehicles to pay to drive in these lanes - the High Occupancy & Toll (HOT) lanes – in the US [12].

So, whilst charging policies have evolved from isolated toll roads to application in cities and strategic routes, the technologies that underpin them have also evolved, becoming more reliable and sophisticated. Standards at critical interfaces enable the apparent simplicity of interoperability;

to ensure that a vehicle owner is able to comply with the many and varied charging policies by the simplest means possible - as easy as roaming with a mobile phone.

Today we see advanced charging and enforcement technologies collecting charges without toll plazas in Australia, Canada, Chile, China, Ireland, Israel, New Zealand, South Africa and the US, amongst many others. The implementation of congestion charging is not without the usual challenges of public and political acceptability.

Recognising the barriers to implementation

Whilst the road network is one of the few utilities that is (mostly) not charged at the point of use, fuel taxation has continued to fund the development and maintenance of roads, bridges and tunnels. New roads, funded through tolls, are often more acceptable, due to the direct, visible and local application of revenues. By comparison, the imposition of road pricing on existing routes requires a 'leap of faith' to accept future benefits; public transport enhancements and a reduction in journey time may not be valued by those paying the charges. Public and political acceptability is a prerequisite for a scheme but user compliance is also necessary to ensure its continued operation, According to Owen et al [22] acceptability may vary with time, peaking when there is sufficient support to enable a scheme to start, falling as details emerge and increasing again as the benefits become visible. Walker [27] shows that road pricing is acceptable if:

- people who are affected have experience that it works;
- it is generally equitable –at least compared to alternatives;
- it is revenue-neutral, or revenues are invested in transport;
- it does not have a high cost overhead.

On the last point, a 5% overhead seems to be achievable. This is much higher than the cost of collecting fuel duty (estimated at 0.2% of the total revenue); but fuel duty does not have traffic management or congestion reduction effects.

Public education and public demonstration are necessary.

2 What technology provides

In this section we provide examples of innovation of road user charging to show what can be achieved.

2.1 The London Congestion Charge

The London congestion charge, included in the manifesto of the Mayor Ken Livingstone, went live on 17 February 2003 with a charge of £5, raised to £8 in July 2005, and to £10 (12 € or $16) on 4 January 2011. It is an area scheme (NOT a cordon) – vehicles must pay if they are used inside the zone, irrespective of whether they cross its boundary.

The system is enforced by fixed cameras located at the boundary of the charging zone, supplemented by 'screen-lines' of cameras inside the zone (Figure 2) which record the vehicle registration mark (VRM) using ANPR, and compare it to the declarations in the payment database. Users who do not pay are subject to a penalty charge of £120.

When the scheme was introduced, congestion in the charging zone fell by 26%. Traffic entering the zone was 17% down, with chargeable vehicles down 31%. Bus patronage increased, and journey time and reliability improved. There was little change in the number of trips to the central area; 50–60% of travellers switched to public transport, 20–30% diverted round the zone, the rest made other adaptations. Net revenues in 2005/06 were £122 million [6].

Figure 1: The Central London Congestion Charging Zone (Courtesy of Transport for London)

Importantly, there was little extra traffic on the road bounding the charging zone. According to TfL [23], 'Total vehicle kilometres on the Inner Ring Road are estimated to have increased by 4% overall'. When the Western Extension was implemented, traffic on its boundary route increased by 4%; on the 'free passage route' between the original Central Zone and the new Western Extension there was no change [24]. The benefits of the scheme, paid for by the revenue, included less congestion, more people using public transport, reduced road traffic emissions, and improved road safety.

Public opinion was equivocal before the scheme's introduction, but shifted in favour when it opened, with opposition levels falling. In 2007 the scheme was extended westwards, approximately doubling the area charged. However, a new Mayor, Boris Johnson, was elected in 2008 with a manifesto commitment to consult on whether to keep the Western Extension, and after consultation it was abolished on 24 December 2010, though the Central Zone continues to operate. January 2011 saw the introduction of account-based charging ("Auto Pay") to improve accessibility and make it easier for users to participate. This also avoids any possibility of a Penalty Charge Notice (PCN).

2.2 The Stockholm Congestion Tax

The political situation leading up to the implementation of the Congestion Tax in Stockholm is covered in Gullberg and Isaksson [15]. Road pricing was first suggested in 1978. After much debate and politicking, a large trial was held between January and July 2006.

The trial scheme was cordon-based (Figure 3), with cameras on gantries at entry and exit points. The tax was charged for Swedish-registered vehicles entering or leaving Stockholm on weekdays from 6 AM to 6.29 PM. Each trip cost SEK 10, 15 or 20, depending on time of day, capped at SEK 60 (£6, 7€, US$9) per day per vehicle. The effects on vehicle traffic were remarkable. In January 2006 traffic dropped 28% [4,18] from 450,000 vehicle passages per day to just over 300,000. The trial was terminated at the end of July 2006 but surprisingly, though traffic increased, it remained 5–10% below 2005 values even though there was no congestion tax!

Figure 2: Central London Congestion Charging Scheme – enforcement site. (Courtesy of Trevor Ellis Consulting Ltd)

There was also no significant diversion onto other routes. On the Essingeleden and Södralänken bypasses, average daily traffic volumes increased by a few percent, mainly outside the rush hours [7]. Of commuter trips crossing the cordon, 24% 'disappeared', but only 1% switched route to avoid the cordon; of the discretionary car trips, 22% disappeared, mainly by changing destinations and decreasing trip frequencies [4].

After a 'Yes' vote in the subsequent referendum, charges were reintroduced in August 2007, causing traffic levels to drop 21%, much as in the trial period. And the effect has increased over time; traffic is 24% less in 2009 than it would have been without the congestion tax [4].

Public acceptability in Stockholm changed significantly before, during and after the trial. Surveys in spring 2004 and 2005 showed 40% support for a congestion charging scheme, falling to 36% just before the trial, with 62% against. However, opinion then shifted dramatically. Support rose to 52% during the trial, and in a referendum after the trial 53% of Stockholm citizens voted to reinstate the charging scheme. It was reintroduced permanently in August 2007 and in December 2007 support stood at 66%. In 2010 it stood at 74% [4,10,18].

Eliasson [8] and Borjesson et al. [4] comment that support for congestion charging is often positive when a scheme is proposed, but it decreases as details emerge; but when it is in place, support increases ('familiarity breeds acceptability') – especially as in Stockholm the positive effects on congestion and pollution were much larger than anticipated. Also people often find that the charges do not affect them as much as they expected. As Eliasson states, this has implications for the political process; elections or referenda should not be held when support for the scheme is lowest. In London, the mayoral election was held before the scheme details were worked out; in Stockholm, the charges had been in place for seven months; in both cases the electoral result was favourable. In contrast, in Edinburgh and Manchester the proposed scheme details had been published but neither had been implemented, and both schemes were rejected in local referenda.

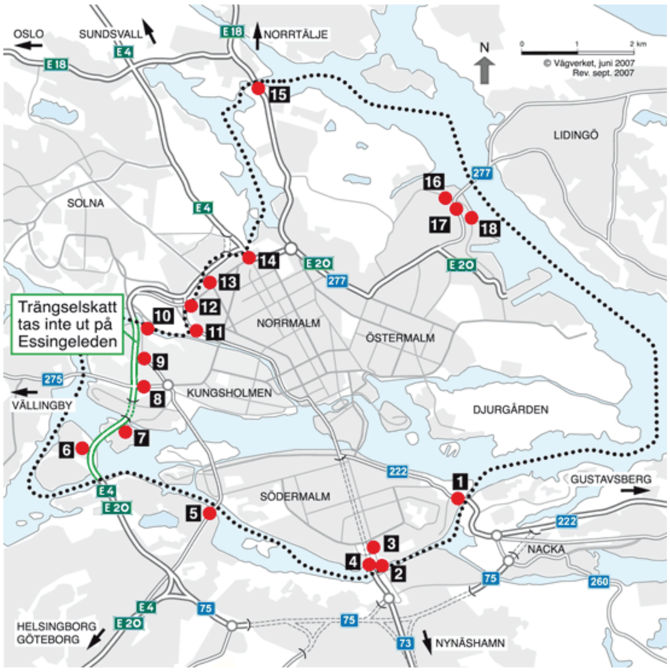

Figure 3: The Stockholm congestion charging scheme boundary. (Courtesy Swedish Transport Agency).

Another noteworthy point is that extra buses were introduced in August 2005, but there was no effect on road traffic until January 2006 when the Congestion Tax came into operation. This suggests that provision of alternative travel modes such as improved public transport will not by itself get people out of their cars. This is consistent with [22].

Thus Stockholm demonstrates convincingly that:
- congestion charging works: congestion is much reduced;
- traffic is not diverted onto other routes: drivers have alternatives other than diversion;
- an initially sceptical public accepts (and votes for) congestion charging once it has experienced its effects; it is now a non-issue in Stockholm – even amongst politicians.

It was suggested that the Stockholm scheme was expensive to run (50% of the revenue spent on collection of the tax), especially compared to Norwegian toll rings, which have 9–10% overhead [1]. But as Hamilton [16] states, the

Norwegian toll rings are for revenue generation, and a reasonable efficiency measure is the revenue generated compared to system costs. But the primary objective in Stockholm was not to collect money, but to improve the traffic situation, so the relevant ratio is the social benefits of congestion reduction in relation to the costs.

Figure 4: The Stockholm congestion tax gantries. (Courtesy Swedish Transport Agency; Photographer: Mikael Ullén)

Transek [26] says that annual revenues were SEK 763M during the trial; annual running costs were SEK 220M. The capital and operating cost for the first year was SEK 2 billion. So it would take 3.5 years for net income to cover the investment cost, or 4 years in socioeconomic cost–benefit terms, both of which are short payback times compared to investments in road infrastructure or public transport, which have a repayment time of 15–25 years at best. The costs were high because it was a trial, and because of more public transport and park-and-ride facilities. The running costs fell to SEK 200 million in 2009, and were expected to be SEK 180 million in 2010, so a comparable scheme could now be implemented at a much lower cost [16].

Under Swedish law, transponder data was not a valid basis for a tax; a licence plate image was needed. Transponders were used in the trial, since the ANPR was initially only 60–70% accurate, whereas transponders are close to 100%. However, an intensive development effort by the contractor, and adding cameras at charging points to capture both front and rear number plates, improved the ANPR accuracy to well above 90% for the trial system in January 2006. Subsequently it was improved still further so that with some manual support the accuracy was consistently 95–99%, and this was deemed adequate for system relaunch in August 2007. Consequently transponders are not currently used [8,16], though they may be introduced in future so that foreign vehicles can be charged.

Plans are also being taken forward to implement congestion charging in the Swedish city of Gothenberg, with an expected go-live of 01 January 2013 [21].

2.3 The Singapore Electronic Road Pricing scheme

This section is based on [5,13,14].

Figure 5: A Singapore ERP gantry at Victoria Street. (Courtesy of Singapore Land Transport Authority)

Singapore had a paper-based road pricing scheme (the Area Licensing Scheme ALS) from 1975. It was a useful traffic management measure, but was cumbersome, labour-intensive and inflexible, and was replaced by an automatic system, the Electronic Road Pricing (ERP) scheme, in 1995, using 2.45 GHz DSRC technology. The contract was worth SGD 196 million, of which half was for equipment for 60 overhead gantries (Figure 5), the other half for 1 million In-vehicle Units (IUs) (Figure 6). The IU cost including installation was SGD 150, which was paid by the government for the 680,000 initial vehicle owners. In 2004 the annual revenue was SGD 80M, with running costs of SGD 16M.

Because the scheme is for traffic management rather than to raise revenue, and to make it acceptable to motorists, annual road tax was reduced and there was a one-off rebate for each vehicle owner, so that overall the ERP was revenue-neutral. There were no cost–benefit assessments, although implementation and operational costs were minimised.

Speeds on road sections are monitored and charges adjusted to deter or to encourage traffic depending on whether the road is congested, confirming that the scheme is for traffic management. There are always viable alternative routes or times of travel for drivers who do not wish to pay, and good public transport alternatives.

In the 2008 revisions to the ERP pricing strategies, public transport capacity was increased, and 2008 vehicle taxes were reduced by SGD 110 million per year, which was higher than the expected SGD 70 million increase in ERP revenue. The cost of managing and maintaining the scheme has increased over time, consistent with the increased number of gantries and IU numbers, but remains at 20–30% of total revenue.

The policy transition from ALS to ERP was small compared to the London scheme – this helped public acceptability, which was not a significant hurdle; public on-street trials by the 3 potential vendors helped ‘sell’ the idea. A potential upgrade to include GNSS is following a similar process.

Figure 6: Singapore's new dual-mode in-vehicle unit with a CashCard. (Courtesy of Singapore Land Transport Authority).

3 Lorry road user charging

Lorry charging was first implemented in New Zealand in the 1970s to tax diesel trucks based on distance travelled, followed by various European schemes (Switzerland, Austria, Germany, Czech Republic, Slovakia). Different technology choices have been made: a hub odometer in New Zealand, a tachograph-based scheme in Switzerland, DSRC schemes in Austria and the first phase of the Czech Republic programme, GNSS plus DSRC in Germany, and GNSS in Slovakia. Felix [11], Walker, Pickford and Blythe [28] and Walker [27] have compared the costs of implementing various existing HGV charging schemes – though comparisons are difficult because it is not always clear whether all costs, especially enforcement costs, have been included.

3.1 Switzerland

The Swiss Heavy Vehicle distance-based charging system (LSVA), based on a modified tachograph but with DSRC and GNSS back-ups, began operation on 1 January 2001. Hofstetter [17] and Walker [27] compare running costs, which are about 6% of revenues.

3.2 Austria

The Austrian lorry tolling scheme was reported on by Kollenhofer [20]. In 2006 the ratio of running costs to revenues was 11% (Table 1).

Annual toll transactions	658m
Toll gantries	450
Total revenue	€825m
Costs/revenue	11 %
Kilometres charged	3.26bn
OBUs (active contracts)	841,600
OBUs actually used	533,400 (63%)
Capture quota	99.7 %
Toll evasion rate	<1 %

Table 1: The Austrian lorry tolling scheme: key figures

3.3 Germany

Satellite-based charging has been used in the German motorway tolling scheme since 2005 [9,19], covering 12,500 km of motorways, with over 650,000 lorries equipped in mid-2008, generating €3.4 billion in revenues in 2007 and €4.4 billion in 2009. Charging is based on motorway segment lengths, so it is not true TDP charging.

The operating costs were expected to be 11–12% of toll income in 2009. There are also significant environmental benefits. By the end of 2009 the proportion of low-emission HGVs had increased dramatically. Vehicles in the low emission categories S5 and EEV14 accounted for less than 1% of the toll mileage in 2005, but 55% by the fourth quarter of 2009. Over the same period, the mileage driven by lorries in the higher emission categories S0, S1 and S2 dropped from 36.5% to 3.7% [2,25].

3.4 Slovakia

Slovakia has used satellite-based charging since January 2010 for lorries of over 3.5 tonnes. Again, it is not true TDP charging; it uses zones, making it simpler to implement. The toll road network includes 622 km of highways and expressways, and 1749 km of first class roads. Tolls apply to freight vehicles & buses over 3.5 tons. There are different toll rates depending on road type, vehicle category, number of axles and emission class. It is enforced by 46 control gantries, and 25 mobile vehicles, with 95 toll officers. Revenues were 1418M€ and 1551 M€ in the first and second years of operation. In comparison the revenue in 2009 from the preceding vignette scheme was 42.5 M€. The efficiency of toll collection is almost 99% [3].

GNSS technology was chosen because it is perceived to have advantages in charging on the dense road network, including maximising toll revenue collection from lower category roads, and it could be implemented in a relatively short time - design, development and commissioning took 11 months. Implementation was also cost-efficient – a 4-year period for return on the investment. There are also low operating costs – a microwave scheme would require 1098 toll gantries.

The scheme was introduced because of the continuing increase of freight traffic on European roads (2.7% per year) while GDP stagnates or decreases. The scheme meets all the conditions of the European directive 2004/52/EC on "Interoperability of electronic toll collection systems in Europe". The on-board unit integrates the 3 key technologies of GPS for positioning, GSM/GPRS for wide-area cellular communication and DSRC for short-range communication. It also provides a platform for introduction of new ITS services including systems for dynamic monitoring, management and regulation of road traffic, cash-less parking management, anti-collision and warning systems, vehicle positioning and navigation systems, obstacle warning and emergency call systems.

4. Recognising the barriers to implementation

Generally political and public acceptability present the most prominent challenges (e.g. UK, South Africa, Chile, US).

Technology is not a barrier. ANPR, DSRC and GNSS/CN are complementary, not competitive; they are mature and proven. But there are cost and performance issues; the choice of charging technology is important but is not the main capex cost. The process design, operational costs, and efficiencies due to interoperability are important, with fuel tax collection cost being used (unfairly) as a benchmark. We need to set expectations and deliver a solution that meets them. At the moment, the road pricing pioneers require politicians and public to take a leap of faith. We need to do a much better job of explaining to motorists why PAYD driving is necessary and inevitable – and is the only way they will get better driving conditions. We need to reinforce the concept of roads as a utility, paid for by users.

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