The Costs and Benefits of Road Pricing: Comparing Nationwide Charging with Project-Based Schemes

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The introduction of widespread road pricing is being considered in the UK and abroad as a means to allocate scarce road space. This paper critically examines the case for road pricing and discusses the optimal scale of charging systems. The costs and benefits of nationwide and project-based schemes are compared using evidence from case studies and economic modelling.

Introduction

Congestion, pollution and related problems have long been associated with road transport. The first section of this paper takes a look at these issues, particularly the costs of congestion and the failure of current policy to curb these costs.

Similarly, road pricing and private sector involvement are not entirely new concepts in transport policy. The second section looks at why they may, however, be underutilised. This section looks at experience with both road pricing and private operators, examining the benefits and costs of each.

One concept that is relatively new in transport policy, at least in the sense that is is now firmly on the political agenda, is national road pricing. Numerous countries are looking at a system of pricing for their surface transportation infrastructure. The final section looks at the costs and benefits of national schemes with the intention of finding an optimal system for sensible road pricing.

The status quo: current problems and failing solutions

The phenomenon of road congestion is one that permeates everyday conversation as much as policy debate. Drivers talk about avoiding traffic jams as much as policymakers talk about solutions to congestion on road networks. However, the different costs of road use observed by drivers and policymakers are behind the problem of congestion itself.

There are several estimates of the external costs of driving in the literature. For the purpose of illustration, one estimate (Sansom, 2001) values these costs in the UK (in pence per vehicle kilometre in 1998 prices) at:

- Infrastructure operating costs/depreciation: 0.42-0.54
- External accident costs: 0.82-1.4
- Air pollution: 0.34-1.7
- Noise: 0.02-0.05
- Climate change: 0.15-0.62

These costs fall on top of the costs of congestion itself, the most notable being wasted time, and as the old saying goes, ‘time is money’. In 2005-06, the worst 10% of journeys in England featured delays totalling 31.3 million hours (see DfT, 2007a). By 2025, congestion may cost £22 billion a year in the UK (Eddington, 2006, p. 49). In the USA, congestion has already been estimated to cost $25 billion a year (Schuitema, 2007, p. 89). Total hidden costs of road use have been estimated at $378 billion to $730 billion per year in the USA (Schuitema, 2007, p. 92)

Essentially, the problem is that current charges do not address the actual marginal costs of drivers using roads. In some areas (namely congested areas), drivers are not charged for the costs they impose on others, whereas in other areas (namely, less congested areas), drivers are charged similar flat rates that are likely more than the cost of their journey. As described in HM Treasury’s 2007 budget’s section on protecting the environment,

> ‘UK transport emissions are primarily priced through a taxation framework - mainly through fuel duty - which provides incentives to individuals and businesses to drive less and use other methods of transport. In setting fuel duty rates, the government also takes into account other external costs of motoring, such as congestion and air pollution, and the need to maintain sound public finances.’
>
> (HM Treasury, 2007, p. 175)

However, it is evident that fuel duties are at best a blunt instrument for dealing with congestion. Thus, many roads go under-priced, and roads are used beyond capacity. In *Managing Our Roads*, the DfT predicted a 20%-25% growth in national traffic by 2015 (DfT, 2003, p. 12). Thus, without new capacity or better use of current capacity, congestion costs will only continue to increase.

Why not just build our way out?

Adding capacity to existing road networks can be difficult for two reasons. First, some areas, particularly congested urban areas, simply do not have room for more roads. Investing in underground or elevated roadways may be possible, but that, of course, brings up the second difficulty of adding capacity - finding the funding to do so. Worldwide, governments are having difficulty finding the money to maintain existing infrastructure and to build new infrastructure. With much existing infrastructure growing older and developing nations competing for resources, costs of construction are increasing. With competition from China and India, the cost of construction materials in the USA rose by 8.5% in 2004 and 12.6% in 2005, driving up the overall cost of construction by 35% since 1998 (Duvall, 2007, p. 2).

In the United States, $20 to $30 billion per year in road maintenance and construction expenditure is derived from income, property and sales taxes, since revenue collected in fuel taxes is insufficient to fund maintenance, let alone new investment, for surface transportation (Schuitema, 2007, p. 87). In the UK, £140 billion in central government spending from 2005 to 2015 is already planned for roadways (DfT, 2007a). Even with this spending, though, congestion is predicted to grow worse, as mentioned above. This expenditure could be funded with the approximately £25 billion in fuel duties and £5 billion in Vehicle Excise Duty (VED) collected each year in the UK (HM Treasury, 2007, p. 281). However, these funds are not earmarked in any way, and as a result, funds collected from road users can be spent on anything (and vice versa, as in the USA). The growing congestion problem, combined with the need to refurbish crumbling infrastructure like the Blackwall Tunnel, a national debt near £500 billion, and the unwillingness of motorists to pay more in already high fuel duties (Scott, 2007) may force the government to find a new way to get more value out of existing capacity and the investment that goes into new capacity.

In short, congestion is getting worse, construction is getting more expensive, and both traditional charges (fuel duty, VED) and construction have thus far proven ineffective.

A better solution?

Road pricing presents an opportunity to get more value for money of both existing capacity and new capacity.

First, tolls represent a more efficient way allocating road space. As mentioned earlier, road use is paid for through fuel duties and VED. These are certainly high, but do not follow a user-pays principle, meaning that people do not 'get what they pay for' or 'pay for what they get' under these methods (Litman, 2005, p. 3). Road users imposing high costs on others do so at no extra charge to themselves. Thus, charges that reflect external costs are more equitable. Some will argue that tolls are regressive in nature, as any toll will make up a larger portion of a small income than a large income. Yet by this logic, current methods of payment are also regressive. With tolls, at least there may be a free alternative road (depending on the scheme), so there is some way of avoiding charging. Fuel duty and VED, on the other hand, are essentially unavoidable for any driver. Furthermore, due to competition between roads, even free alternatives should see a benefit from road pricing (see below). Beyond that, if road pricing enables a lower rate of fuel duty or VED, lower-income drivers will be better off. Thus, to the extent that tolls are regressive, they will (absent an exploitation of monopoly power (see below)) be no more regressive than the status quo, and will provide a way to improve the quality of transport for the poor.

Overall, since tolls are an improved method of payment compared with existing taxes, there will be better value for money. As noted by Schuitema, 'Congestion, in essence, reduces the value of the community's investment in [road infrastructure] by causing actual capacity to fall far below physical capacity" (2007, p. 84). Because of congestion, a road or network of roads becomes less able to operate at full capacity (and as was intended when it was constructed) within a given amount of time. If road pricing, with its ability to better manage demand, is used for road funding over less effective traditional methods, then the value of investment in infrastructure increases, and commuters enjoy better value for money.

Second, as explored below, tolls open the door for private sector involvement in the surface transportation sector. Private operators can, within a regulatory framework, take on risks of financing new roads with tolls, and also operate an existing road under profit-maximising incentives. The efficiency and risk-transfer benefits of this opportunity are explored below.

The potential of road pricing

Pricing in theory and practice

This section gives a basic overview of the principles behind road pricing and looks at case studies of road pricing in practice. This is by no means an exhaustive review of the performance of charging schemes worldwide, but, as discussed below, the ability of charging to have a substantial impact on congestion is examined.

How charging works

As mentioned above, current charges do not properly address the variable costs of driving, including external effects on the environment and the effect vehicles have on slowing down other traffic. Thus, road pricing attempts to internalise those costs for the driver. Whereas congested roads previously went under-priced, now, the price paid by drivers will more accurately reflect the cost of using the road. As a result, drivers who do not value the ability to travel *on that road at that time* will not drive on it, and the road will become less congested. The drivers who are willing to pay will enjoy a reduction in their journey times as well as a 'toll road bonus' (see Maunsell, 2005, p. 67) - more reliable travel through reduced variation in journey times. Drivers who are not willing to pay a price will either:

- Drive at a different time
- Change destinations
- Change routes to the same destination
- Change modes of transportation
- Decide not to travel

With these in mind, it is important to note possible unintended effects of changing the price (or toll) of a road. Drivers who change to different routes may cause congestion on smaller roads they are diverted to. This diversion, as well as excessive changes in destination (or route, for that matter) can harm businesses or local areas in general. Which decision a driver makes will depend on the alternatives available, so these must be considered when implementing a charging scheme.

> 'The reason congestion pricing based directly on roadway congestion is more accurate and efficient than time-of-day pricing is that it approximates the marginal external costs imposed by drivers more closely than time-of-day pricing, which uses the average marginal external cost imposed by drivers over a given time period (during peak periods, for example). In order to better understand this difference, imagine a large group of friends meeting for an expensive dinner and, in order to reduce the bookkeeping, the bill is divided evenly amongst each friend (as in time of-day pricing). Since each individual friend could not lower the group bill significantly by ordering less, there is reason for excessive consumption . If, however, every individual friend is charged according to the amount of food he orders (as in direct congestion pricing) there is reason for self-restraint.'
>
> (Schuitema, 2007, pp. 95-96)

Of course, there may be sacrifices in simplicity or lower operating costs in return for using a pricing scheme like this. Thus, the exact benefits between different methods should be weighed against the relative costs of implementing them.

Charging in practice

Singapore

The first congestion charging scheme in the world, the time-of-day priced system implemented in Singapore's Central Business District in 1975, immediately reduced by 73% the number of private cars crossing the cordon into the Central Business District, increased carpooling by 30% and doubled bus usage, with only slight traffic diversion. Following large increases in income and car ownership, congestion is still 31% lower than before charges were implemented, with an extension of charging hours and the implementation of electronic tolling. Revenues for the project, adding up to around €40-50 million per year, far exceed the annual operating costs of approximately €8 million (see Schuitema, 2007, p. 99).

Norway

In Norway, there are cordon-pricing schemes around the cities of Bergen, Oslo, and Trondheim. As noted by Langmyrh, 'Following the introduction of the [Trondheim] scheme, there was a 10% decrease in traffic passing the ring both in the peak and non-peak charging hours. The traffic increase in the evenings and weekends (with no fees) was slightly above 8%' (2001, p. 69).

As discussed earlier, some local authorities have worried about the effects road pricing within their areas may have on the amount of people that travel to their cities (see Glaister and Graham, 2004, p. 115). This was the case in Norway, with 'harm to the city centre' being cited as the most common argument against road pricing before the scheme's implementation (see Langmyrh, 2001, p. 77). While it is true that excessive pricing could deter some from entering a charged area by car, there is still the potential for other methods of transport into city centres to be used. Furthermore, these prices can be signals for investment, in that, realising the amount people are willing to pay to visit a certain city, companies can more accurately assess the potential value of investing there. The increased mobility to be had from road pricing may further increase these gains. Indeed, in Norway, 'increased mobility was regarded as an asset that could help attract the flourishing oil industry to the region' (ibid., p. 72). The reduced costs to businesses in saved time and fuel due to lower congestion can both make existing local businesses more competitive and attract new businesses to fuel expansion. After charging was implemented, the effects on the city centre were mostly positive or only slightly negative. In fact, after implementation 'harm to the city centre' was hardly cited as a reason against road pricing (see ibid., p. 77).

The Norwegian system also demonstrates the benefit of having new revenue raised through tolling:

> 'The revenues are earmarked for a transport investment package financed by 60% user fees and 40% state funds. From this, 80% is to be used for road building. The remainder is to be invested in public transport, safety and environmental improvement projects. The total 'Trondheim package' amounts to more than NOK2 billion (US$200 million) over a 15-year period.'
>
> (Langmyrh, 2001, p. 69)

In fact, in Norway, demand management was not an accepted rationale for tolling at the outset of the scheme. While this may be less of a problem in Britain, as 87% of chamber of commerce members surveyed would advocate some type of road pricing to relieve congestion (DfT, 2007b), it does show that the aim of road pricing is not solely to discourage more people from driving by charging them more, but to have a better method for collecting and allocating funds for road investment. Langmyrh described a key motivation behind congestion pricing: ‘rush-hour traffic is responsible for the need to expand road capacity and consequently should be charged extra’, showing how both demand management and road financing can be accomplished through tolling (2001, pp. 69-70).

Orange County, California: SR-91

On this road in California, a ‘High-Occupancy Toll’ (HOT) lane is available for car shares and any drivers willing to pay a toll to use a premium lane. The system is operated by a private firm. Charges vary by the time of day, and are highest during peak hours. In peak periods, drivers can save up to 35% in journey time. Furthermore, in the first six months after opening the tolled lanes, delays fell from 30-45 minutes to 5-10 minutes on the free alternative lanes (see Sullivan, 2000). Of course, some congestion relief would be expected from constructing a new lane. However, the fact that the lane requires drivers to either carpool or pay a charge to use it helps prevent the lane becoming congested so it can continue to offer premium service.

San Diego, California: I-15

On this congested road in San Diego, authorities opted to change an un-priced ‘High Occupancy Vehicle’ (HOV) lane into a HOT lane, allowing solo drivers to use the road for a toll. Here, tolls vary in real-time based on the actual amount of congestion on the road. Schuitema discusses the impact of this change:

> ‘The overall impact … has been to increase the average daily traffic on the HOV lanes from 9,400 to 20,000 vehicles per day and to double the number of daily carpools to more than 15,000 each day. This change corresponds to a two to three percent decrease in traffic volume on the main, "free" lanes as well. This decrease in congestion along I-15 has brought reduced travel time, reliability of on-time arrival, and improved safety for all commuters. As a result … the economic costs of congestion along the I-15 corridor to the San Diego region dropped eighteen percent during the first year of operation alone.’
>
> (Schuitema, 2007, pp. 105-106)

Chicago Skyway

The Chicago Skyway is a tolled alternative road to some of the severely congested roads around the city of Chicago. Average time savings on the Skyway for road users are approximately 22 minutes, with savings as high as 35 minutes possible (Maunsell, 2005, p. 1). In addition, they enjoy improved reliability of service. Maunsell found that the standard deviation of mean time savings was 5 minutes, and thus valued the ‘toll road bonus’ of reliability at 5 minutes. While this method seems questionable, in that higher standard deviations will result in higher bonuses (it would seem more desirable to have as high as possible mean time savings with as low as possible standard deviation), Maunsell still notes that the 'main benefit was the improved reliability of travel time' (2005, pp. 67).

As of the Maunsell study in 2005, about 13% of the region's peak period traffic uses the Skyway, though this is predicted to rise to 20% by 2020 (ibid., p. 75). As the Skyway currently operates at about one third of capacity during these congested times of the day (ibid., p. 1), higher use of the Skyway should help to relieve some congestion in the region. Of course, it does seem that further improvements around the city are necessary to tackle congestion, possibly through charging on other routes, and possibly through improved transportation provision in the region.

M6 Toll

The M6 Toll is Britain's first tolled motorway (see Highways Agency, 2005). It was built through a Design Build Finance and Operate (DBFO) contract with the company Midland Express Limited. The M6 Toll provides an alternative route to the most congested portions of the M6 through the West Midlands region. Since opening in December 2003, the road provides users with journey times that are between 4 and 18 minutes quicker than the un-tolled M6 during peak hours (ibid., p. 8). For southbound journeys, journey times are 43% faster on the M6 Toll than the M6 in the morning peak (23 minutes compared with 41 minutes). Still, travel speeds have improved on the M6 as well. On the northbound side, average speeds throughout the day have improved between 5 and 20 km/h, with peak period speeds rising 20% since the opening of the M6 toll (50 km/h to 60 km/h). Flows on the southbound side have improved from the average 30 km/h during peak periods in 2003. Furthermore, congested periods during the day have also shortened since the opening of the M6 Toll (ibid., p. 9).

In addition, safety has improved on the M6 since the opening of the M6 toll, with personal injury accidents significantly reduced and accidents involving death or serious injury down by over 50% since the late 1990s. As for the M6 toll, accident rates are less than half the national average for a motorway (ibid., pp. 13-14).

The London Congestion Charge

Following a long history and much publicity, congestion charging was introduced in London in 2003 (see TfL, 2007a). London uses an 'area charging' scheme, so drivers who drive within the charged area between 7am and 6:30pm are charged. Congestion in Central London dropped 30% in 2003 and 2004, with average delays for vehicles dropping by 0.7 minutes per kilometre (from 2.3 to 1.6) (ibid., p. 36). Congestion has worsened somewhat in the past two years, however, with reduction in delays in 2005 of 22% and just 8% in 2006 (though quite varied throughout the year) when compared with 2002. This has been largely because of initiatives to improve safety for pedestrians and cyclists, but also because of a 90% increase in the duration of street works (i.e. utilities) to replace aging infrastructure within the area (ibid., p. 38).

The Inner Ring Road, which forms the boundary of the charging area, has not been victim to excessive diversions since charging has begun. TfL actually estimated a

20% reduction in congestion after charging was implemented thanks to better traffic management, and congestion was still down 10% in 2005 (ibid., p. 40). These figures may be somewhat misleading due to major road works on the ring road in 2002 before charging began. With this in mind, TfL notes that there may be some evidence of slightly increasing congestion on the Ring Road, as well as main radial routes into London and main roads in Inner London, but that conditions are 'comparable to, or marginally better than those in 2002 before the introduction of charging' (ibid., p. 46). Again, these trends may be due to road works or other interventions that affect effective network capacity.

Bus services in central London have also improved since the charge has been implemented. While journey times have not decreased substantially (mostly due to the time it takes for the increased amount of passengers to get on and off buses), journey reliability, measured in excess waiting time at bus stops due to buses being stuck in traffic, decreased 30% in the first year of charging, 18% in the second year, and 4% in the third year, with slight deterioration of the benefits since (ibid., p. 60). These benefits have come as a result of the charge as well as investment in robust schedules, route supervision and quality incentive contracts.

In addition, despite many fears, there seems to be 'No general evidence of any clear differential impact of the central London congestion charging scheme on business activity' (ibid., p. 95).

While studies are certainly preliminary and proper evaluations will take time to observe longer-term effects, initial results suggest that wider economic trends, political events and other developments in London, for example, the terrorist bombings of July 2005 or the closing of the Central Line after the Chancery Lane derailment, are responsible for most effects on business observed since charging has been implemented, as opposed to charging itself.

Tables 1 and 2 (from TfL, 2007a, p. 114) show the costs, revenues and use of revenues for the 2006-2007 fiscal year. The £123 million of net revenue has gone towards various transport improvements.

Table 1: **Scheme revenues and costs, financial year 2006/2007 (£ million provisional)**

Revenues
Standard daily vehicle charges (£8): 125
Fleet vehicle daily charges (£7): 27
Resident vehicles (£4 per week): 6
Enforcement income: 55
Total revenues: 213
Total operation and administration costs: -90

Net revenues: 123

Table 2: **Application of scheme revenues, financial year 2006/2007 (£ million provisional)**

Bus network operations: 101
Contributions to major enhancements of London's bus garages, stations, stops and shelters; to bus priority and real-time customer information systems; and to bus operations and support activities.

Roads and bridges: 14
Contributions to investing in programmes to improve the quality of street conditions, including reconstructing and resurfacing carriageways and footways and upgrading and strengthening structures.

Road safety: 5
Contributions to measures to reduce road casualties, both on TfL roads and borough roads.

Walking and cycling: 3
Contributions to a programme of improvements for pedestrians, both on TfL roads and on borough roads; includes contributions to borough local transport improvements.

Total: 123

Overall, TfL's cost benefit analysis estimates annual net benefits to society (including the operating costs and revenues) of approximately £99 million per year with the current £8 charge (see TfL, 2007b).

Some lessons learned

Each of these cases shows some of the possible benefits of road pricing, with both congestion relief and revenue-raising possible. It is also possible to minimise unanticipated negative effects of charging, including improper traffic diversion. As seen in London and Norway, business effects are not necessarily adverse, and with responsible management, increased mobility can provide gains to businesses. Indeed, worsening congestion is likely to cost businesses as well.

There is the potential for these benefits to be realised around Britain. Twenty per cent of people driving in peak hours could change the time they drive (DfT, 2004, section 3.28). Since 71% of cars at peak hours have single occupants, encouraging car sharing by offering exemptions in HOT lanes could substantially reduce congestion. Further, as only half of those single drivers are commuters, they may be able to easily change their time of travel (ibid., section 3.29).

An important task, then, is to find an optimal overall transport system that makes the most effective use of road pricing. In London, for instance, the benefits of charging have been reduced by street works. In addition, finding an optimal use of revenue is an important consideration. The remainder of this paper will look at some ways to accomplish this task.

Private sector involvement

Another new technique in road investment and management is the use of private sector financiers and operators in place of traditional contracting methods. Though controversial, there is evidence of several benefits to private sector involvement in providing both priced and un-priced roads. This section explores three benefits - efficient operation, risk transfer, and access to private capita - as well as risks that arguably should be addressed to protect the 'public interest'.

Efficient operation

Simply put, experience in the UK and abroad has shown that private road operators manage roads better than their public sector counterparts. Since the advent of the Private Finance Initiative in the UK, roads built under DBFO (design-build-finance-operate) agreements have helped to spawn the growth of a road operating industry in the UK (see Highways Agency, n.d.). In these agreements, the government has companies bid to construct a road and operate it in return for 'shadow tolls'. These payments are referred to as such because drivers pay no road user charges, but the government pays the operator a flat rate per car that uses the road, provided that quality standards and free-flowing traffic are maintained. That is, if a road becomes too congested, or underperforms in other ways, the operator will not be paid. In extreme cases, the operator can lose control of the road.

Thus, with output standards set, private operators are incentivised to minimise costs and find innovative ways to maintain steady traffic flow and road quality. Evaluation by the UK Highways Agency has found 'marginal to substantial' cost savings with DBFO agreements, with taxpayers benefiting from better value for money. In an interview, Graham Taylor, the Group Manager of Private Finance Policy at the Highways Agency, said 'PFI roads are simply better maintained than the roads around them … private operators do not leave things until they become problems. They fix them before they become problems. This is a key lesson, and it stems from a life-cycle approach to asset management' (Bain, 2005). Indeed, a study by HM Treasury found 88% of public private partnership projects were delivered early or on-time, with any cost overruns borne by the private sector, while public projects were delivered late 70% of the time and over-budget 73 % of the time (see Duvall, 2007, p. 7).

The UK is not alone in seeing results like these. A survey of Danish roads found that privately delivered roads were of lower cost than publicly delivered roads without a loss of quality (see Blom-Hansen, 2003). Poole (2007a, p. 5) described this type of efficiency as 'value engineering', discussing the case where the state of Virginia had a plan to produce a road at $3 billion, whereas a private company estimated costs at $1 billion by eliminating 'bells and whistles'. The controversial lease of the Chicago Skyway has been followed by substantial improvements in maintenance, thanks to strict contract provisions for the removal of potholes or dead animals (see Thornton, 2007). In addition, there is the potential for major innovations to be introduced and perfected by a private operator, such as variable pricing, which has improved efficiency (as discussed above), and was first introduced by a private operator in California (see Poole, 2007a). In contrast, in Indiana, in a frightening revelation, the now privately-operated Indiana Toll Road was in fact *losing* money by collecting tolls when it was publicly owned. As it cost the state about 34 cents to collect a toll of 15 cents, 'Governor [Mitch] Daniels half-joked that the toll road should be shifted to the honor system' (Seagal, 2007).

Just as reducing congestion is important to increasing the value of a road, so is operating it efficiently. For toll roads, or almost any asset, this at least means breaking even. Outcomes like that in Indiana are likely behind Poole's (2007a, p. 7) comment:

> 'The single most important factor driving the higher valuation accorded to concession toll road deals is the certainty of being able to raise toll rates over the life of the agreement. No one has yet figured out a way to bind future elected officials from interfering in the toll-setting decisions of state toll agencies - and the capital markets take that into account in judging what they will finance.'

As described by Thornton (2007), a private operator has an advantage in that it can raise prices to reduce congestion or cover costs without 'being penalized in the voting booth'.

Comparing the results of politically driven pricing in areas like pre-concession Indiana with other examples, like the California toll company that developed variable pricing (ibid., p. 5) shows that efficiency in maintaining and pricing a road (in the absence of excessive monopoly power - see below) can be two ways that private toll road operators deliver better value for money.

Risk transfer

In addition to the improvements in quality, allowing for private sector involvement in road provision allows for risk transfer to private operators. As noted by the Highways Agency, a DBFO contract allows for the transfer of risks such as construction risk (which, under traditional contracting, resulted in 28% cost increases between tendering and outturn for the government), delay in provision, design risk, changes of law (i.e. tax changes), traffic risk and interest rate risk involved in financing (see Highways Agency, n.d.). After analysis using a public-sector comparator, it was determined that the private sector would manage these risks better. Thus, risk transfer is not only undertaken for 'off-balance sheet accounting treatment', but to achieve better value for taxpayers.

Access to private capital

Private financing enables strained public budgets to benefit from a new source of capital and of income, in the case of toll road concessions. For shadow-tolled roads, it is possible for the government to make small, regular payments on a road investment and avoid the need for high borrowing or taxes. With concession payments, in addition to having a private operator finance the construction and maintenance of a particular road, the government can receive money to fund major new investments or support other financial undertakings.

In Indiana, the $3.86 billion payment was used to begin funding the 'Major Moves' projects around the state, revitalising transport infrastructure in ways previously thought impossible. The payment is also bringing in about $500,000 in interest every day (Seagal, 2007). In Chicago, the $1.83 billion dollar concession payment has helped to fund local projects and currently earns interest to the tune of $25 million a year, near the amount it used to collect in tolls (Scott, 2007). Alternatively, the concession payment on the Pocahontas Parkway has been supplemented with a plan for revenue sharing throughout the term of the lease (see US House of Representatives, 2007).

The government's use of capital only represents one side of the benefits, however. One must not forget that investors also gain. The ability of privately operated toll roads to offer steady cash flows with relatively low risk has made them an attractive new investment to many in the financial community, particularly insurance companies and pension funds looking for long-term investments (see Thornton, 2007).

Thus there is the potential for privately operated toll roads to yield substantial benefits compared with publicly operated toll roads. Privately operated roads will be of higher value to the public thanks to better management, proper pricing, and risk transfer. In addition, access to new funds will help the public sector make other necessary investments while private investors enjoy returns on their capital. However, it may be necessary to address certain risks to protect the 'public interest' during private toll road provision.

Monopoly power

As discussed earlier, road pricing will essentially result in one of five effects (changing time of travel, route, destination, mode of travel, or not travelling) if travellers are not willing to pay a toll. Some travellers, namely people going to work, travelling home, or making other essential trips along a particular route, will be less able to change their travel behaviour. In the absence of substitute roads or methods of transportation, they will overall have less ability to pay tolls. Thus, roads with high proportions of these travellers and few available substitutes will have an *inelastic demand* for space on that road. In the hands of a private toll operator, this could result in monopoly power, which could lead to very high toll increases that harm drivers.

Thankfully, there are techniques for dealing with this potential problem. First, it is possible to pick projects with sufficient substitutes (depending on the tolling system - see below). In London, for instance, it seems that it was easy enough for much traffic to travel outside of peak hours, use public transportation, or drive outside of the charged zone. Thus, in situations like this, a private operator will not raise tolls as high as possible, as this will lead to a loss of customers.

In other projects, it is possible to put a cap on toll increases, often indexed to inflation or economic growth, as in Chicago or Indiana (see US House of Representatives, 2007). Similarly, a rate of return on investment limit can be placed on private operators. In Orange County, California, for example, any revenues in excess of a 175% rate of return (still a sizeable return) were returned to the State (Schuitema, 2007, p. 104). It is important to note that techniques like these are merely caps, and that operators may price below such levels if it will allow them to draw more customers. However, in controlling congestion, it is important to realise that efficient pricing may be hard to achieve with a cap.

Alternatively, a technique described by DeCorla-Souza as Concurrent Real and Shadow Tolling (aka CRAST) may provide a better way of aligning the incentive to maximise profits with the incentive to optimise traffic flows (see DeCorla-Souza, 2006). In CRAST, the private operator sets tolls, but all real tolls collected are sent to the government, while the operator is paid a shadow toll (like the current UK system) for each car that passes at free-flow speeds. Thus, the private operator will set prices efficiently to keep traffic flowing, and will not have the ability to exercise any monopoly power. As noted by Poole (2007b), 'The pricing mechanism could be focused on optimizing use, rather than meeting debt-service schedules'.

System fragmentation

In the US debate over road pricing and public private partnerships, some have expressed concerns that different pricing schemes will fragment the nation's transportation system (see DeFazio, 2007). With reference to the European Commission Directive on Road Charging Interoperability, Glaister and Graham also mention the potential for local schemes to be incompatible (2004, p. 113). There are essentially two ways in which this could happen - traffic distortion through pricing and incompatible technology.

If pricing causes improper traffic diversion, then pricing that road (publicly or privately) may harm transportation systems. For instance, if tolling major roads causes traffic diversion onto local roads, then road pricing will have adverse effects. The reason this could be worse with a private operator is if the operator had monopoly power, and raised prices to earn more profits without feeling the effects of the traffic it diverted. This problem can be minimised with appropriate controls on monopoly power, particularly CRAST, which will in fact give the opposite incentive - to have *minimal* diversion, and to maintain the best flow of traffic on the road. Alternatively, as in one concession in Canada, on Highway-407, ETR, the operator can be penalised for pricing that causes traffic diversion onto local roads (see Samuel, 2003). The potential for diversion of traffic should be considered during project design, and this may have an impact on the type of scheme implemented (see final section).

If different tolling systems around the nation (or a larger area) all used incompatible forms of technology, certainly there could be inefficiencies due to high transaction costs. The USA has experience with 50 different states in addition to bridge and tunnel authorities operating its roads (see Duvall, 2007, p. 11), but one obstacle to more harmonious toll operations is the continued use of cash lanes in addition to electronic toll lanes. These cash lanes often slow down traffic. Despite the contentions of some that private operators would create more problems, it is more likely that they would help to speed along the transition to better interoperability. Concession agreements can include electronic tolling and a standard technology can be used across the country. Indeed, private operators would have the incentive to make their particular facility compatible with others in order to keep their customers happy. Poole (2007c) mentions how the EZ-Pass network of electronic tolling stretches from Maine to Virginia, and Massachusetts to Illinois - an area greater than the size of the UK, and how Chile has its own network of electronic tolling. Thus, considering the start-up costs of electronic tolling (particularly with adding Automatic Number Plate Recognition enforcement to eliminate the need for cash lanes) it is more likely that privately operated toll roads would move towards a smoothly operating system.

Overall, it is important to note that although profit-maximising incentives encourage private operators to allocate road space efficiently, the public maintains ownership of the road. In the event of unacceptable quality or monopolistic pricing, the government can assume control of a road (with fair compensation if necessary, depending on the concession agreement). Some agreements even include ‘termination at will’ clauses, as with the Pocahontas Parkway (see US House of Representatives, 2007).

Private operation is therefore likely to increase the benefits of road pricing. In London, for example, output incentives like those on shadow-tolled roads may have encouraged better management of street works to minimise congestion. The performance of private operators in Chicago and the UK certainly suggests that given the incentive to minimise interruptions of service, private operators will do just that.

Just as road pricing can provide economic benefits by reducing congestion, private operation promises to improve pricing and maintenance while reducing risk and the level of taxpayer subsidy. Barriers to private sector involvement in the operation of roads are therefore highly detrimental.

Realising potential: finding an optimal system of charging

Possible benefits of nationwide charging

In *Pricing Our Roads: Vision and* Reality, Glaister and Graham (2004) provide a detailed analysis of how nationwide charging could work. This section gives a brief overview of their work in order to assess the possible benefits of implementing a road pricing scheme across the UK.

Glaister and Graham modelled the economic benefits of numerous national charging schemes. Such charges would aim to internalise the costs of road use by charging per kilometre travelled. More specifically, schemes with high and low estimates of environmental charges as well as congestion charges (by different times of the week, types of road, and ‘busy’ or ‘not busy’ directions) are analysed in three scenarios: adding to existing fuel duties and VED, a revenue-neutral scenario where rebates to drivers offset the new revenues to the Exchequer and a fully efficient scenario where subsidies to bus and rail travel are eliminated. The net benefit of each policy includes estimates of time savings, environmental cost savings and changes in revenues (newly collected road user charges, drops in fuel duty, etc.).

As no national road pricing scheme has been implemented anywhere yet, this study provides some of the best estimates of the economic benefits of widespread charging. Furthermore, as the model does not account for traffic growth, car sharing, or time of day shifts, the benefits of road pricing could be larger than the figures generated. To review a few figures:

- With low environmental charges added to existing charges, net benefits come to around £0.44 billion annually
- Adding a congestion charge increases net benefits to £2.75 billion a year
- Using the higher estimate of environmental charges brings net benefits to £4.47 billion a year
- Changing to a revenue neutral scheme with a low environmental charge and congestion charge yields net benefits of £1.76 billion
- A full economic efficiency model with the high environmental charge and congestion charge produces net benefits of £4.29 billion annually

While much of these economic benefits come in the form of reduced travel time thanks to congestion relief, the authors note that congestion charging is only in effect in certain areas. In other areas, particularly rural areas, the only charge levied is the environmental charge. This leads the authors to describe congestion as a 'localised problem' (ibid.) and begs the question - how widely should charging be implemented?

In looking at the benefits of extending charging into areas where only an environmental charge would be levied, one must compare this charge with the currently used fuel duties and VED and their relative ability to produce positive *environmental* cost reduction.

First, we can look at the short-term incentives each charge imposes on drivers. Fuel duties, simply enough, strengthen the incentive drivers have to use less fuel (as they pay for fuel, they always have this incentive, the duty only strengthens it). This translates to driving in the most fuel-efficient manner - shortening distances where possible, reducing time idling in congestion (or just idling), and driving at speeds that optimize fuel use. Environmental charges, on the other hand, give drivers the incentive only to drive less distance. The extent to which either of these is effective depends on the alternative routes or modes of transport available to drivers. In many rural areas, it may be hard for drivers to shorten the distance they drive or find alternative methods of transportation. This may impair the effectiveness of either charge, except to deter unnecessary trips.

Next, a look at the long-run incentives shows other subtle differences in the charges. Fuel duties give the incentive to buy fuel-efficient cars. As VED is differentiated by vehicle class, it provides an incentive to buy environmentally friendly cars. Environmental charges would do the same *if* there were differential charges for different kinds of cars. No such scheme has been modelled yet.

Thus, while the differences in these exact charges may be subtle, their intentions can overlap in practice. With revenue-neutral type schemes, it is possible to reduce fuel duties, and as Glaister and Graham mention, this will likely be necessary for political acceptance of road pricing (ibid., p. 112-113). However, as noted in the Road Pricing Feasibility Scheme (RPFS) supplement 'Road User Charging Pricing Schemes', this will give the impression that 'the cost of using a car with low fuel-efficiency was going down while that of using one with high fuel-efficiency was going up' (DfT, 2004, p. 27). Such a change may have implications for successful impacts on driver behaviour, with the logic of charges becoming harder to understand than with the more familiar congestion charge. In essence, the logic drivers employ would change from: 'Charges will be highest when and where traffic is expected to be busiest' to 'Charges will be highest when and where extra traffic is expected to be most unwelcome' (ibid.).

Thus, the relative benefits of an environmental charge over the fuel duty and VED are questionable. As noted in Appendix A of the RPFS, fuel duty and VED are effective in promoting fuel efficiency and reducing carbon emissions. It is in targeting location specific infrastructure costs and congestion costs that they really fall short.

Therefore, it seems that the main benefit of road pricing is to relieve congestion. Indeed, even only relieving congestion will reduce environmental costs: 'This is due to the fact that better traffic flow causes less [sic] emissions per kilometre driven. Emissions such as volatile organic compounds (VOC) and carbon monoxide (CO) - both are main components in smog – are 250% higher at congestion than when the traffic flows' (Transek, 2002, p. 22).

In deciding on a scope for charging, there appears to be prudence in limiting charging to congested areas. Glaister and Graham discuss the benefit of having only 'charges in particular areas, on particular road types and where charges should be above a given threshold' (2004, p. 104). There is little change in economic benefit by excluding rural areas (ibid., p. 100). The challenge from here is deciding how to achieve these benefits in practice - optimising system structure and cost.

Costs of nationwide charging

The 'Implementing Road Pricing' supplement to the RPFS estimates the cost of a national scheme. This study looked at the different set-up and operating costs of different road pricing techniques. The model most akin to the full nationwide charging discussed above was Scenario 9 in this study, where all UK roads are priced. In order to do this, all vehicles in he UK must be fitted with a complex hybrid On-Board Unit (OBU) that tracks distance via the Galileo satellite network. Automated Number Plate Recognition (ANPR) technology is used for enforcement. As Galileo technology is still in development, costs may fall, and thus, three levels were estimated for the OBU: £100, £250 and £525 per unit. In addition, communication costs for each user may vary as this satellite technology improves, so three levels were estimated for these costs as well: £12, £24, and £36 per user per year.

With these varying estimates:

- Set-up costs range from £23.4 billion to £62 billion
- Annual operating costs range from £4 billion to £5.4 billion
- 20-year totals range from £105 billion to £170 billion

The study also looked at less expansive scopes of charging, namely:

- Scenario 7a - Charging only urban areas and 15-mile “Travel to Work” areas around them with optional GPS (rather than Galileo) OBUs: £14.7-£17.6 billion to set up, £2.4 - £3 billion a year to run, and £63.1 - £78.7 billion over 20 years
- Scenario 7b - Same as 7a with mandatory GPS OBU’s: £14.8-£17.6 billion to set up, £2.2-£2.8 billion a year to run, and £59.1 - £74.7 billion total over 20 years
- Scenario 8 - Including congested trunk roads in 7b: £18.7-£22.4 billion to set up, £2.7-£3.6 billion a year to run, and £75.3 - £95 billion total over 20 years

The cost estimates for Scenarios 7a, 7b, and 8 are lower than those for Scenario 9 (full road pricing) for two reasons. First, not all vehicles are equipped with OBUs, so set-up costs are lower. However, just as the non-mandatory OBU scheme (7a) has higher operating costs because of the increased need for ANPR enforcement, all of these schemes may encounter unexpected expenses when non-equipped cars enter charging areas. Second, the reduced-scope schemes use less sophisticated technology. However, this GPS technology is less accurate than Galileo is predicted to be, with possible errors of up to 200m and delays of up to 15 seconds possible in 35% of London (Tolltrans, 2007).

Thus, with these satellite-based programs, costs are questionably large, while benefits are questionably small by comparison. At the very least, charging all UK roads, with costs starting at £105 billion and maximum benefits at £89.5 billion over 20 years, does not seem to be a worthwhile investment. However, with the possible far-reaching benefits of charging, it is worth finding an alternative solution. Even the reduced-scale satellite models, though, do not seem to provide good value for money, with possible cost overruns likely and no guarantees on system accuracy.

Moving towards a manageable system

In addition to the above mentioned satellite-based models, the RPFS looked at the costs of road pricing schemes using more conventional technology for tolling - Dedicated Short-Range Communications OBUs (DSRC) based on microwave technology, backed up with ANPR enforcement. These OBUs only cost £15 per unit. Over 20 years, approximate costs for different schemes include:

- £30 billion for urban areas with two zones
- £37 billion to include congested motorways with the urban areas
- £11 billion to add premium tolled lanes to congested motorways
- £17.7 billion to toll newly constructed roads

It is easy enough to see that these alternatives are much cheaper to implement than the satellite-based schemes. The important issue, then, is whether or not there is a substantial reduction in benefits. To determine this, consider three questions:

How will user behaviour change?

The difference between satellite charging and DSRC charging is whether cars are charged by distance or when crossing cordons. As mentioned above, there have been successful congestion charging schemes tolling users both entering urban areas and driving on tolled motorways. The advantage of distance-based charging, i.e. that it allows for a distance-based environmental charge, is not necessarily much greater than conventional fuel duties, as mentioned earlier.

In addition, as mentioned in the RPFS supplement 'Road User Charging Pricing Structures', a crucial part of properly influencing behaviour in real-time is giving motorists a chance to change their route 'upstream' of charging points (p. 26). Systems for displaying charges are in place on roads like SR-91 and I-15, but a new system would have to be devised for either alerting drivers to changes in price via their OBUs or other roadside infrastructure. This will likely change the cost estimates currently in place, probably upwards.

Finally, in evaluating the effects of road pricing, as policymakers, it is important to look at transportation options in an integrated context. Pricing roads will have an impact on the use of alternative methods of transportation (bus, rail, etc.). Generally, as the cost of driving increases, more passengers will switch to bus and rail trips. In evaluating the impact of road pricing, as mentioned before, the exact change in behaviour depends on the alternative choices available to road users. There can be 5 effects (changing time of travel, route, destination, mode of travel, or not travelling). Which result occurs depends on when and where the charge is levied. This means, of course, that when a traveller has the greatest ability to change the time at which they travel (for example, moving outside of peak travel time), they will do so. When it is easiest to change routes (for example, to avoid the routes most necessary for commuters) they will do so, etc. In pursuing an integrated transport policy, it is important to consider what opportunities exist for modal shift when roads are priced, and to what extent modal shift is desirable. The social desirability of shifting to a particular mode at any given time will depend on the relative social costs of different modes. For instance, a road-pricing scheme aimed at giving travellers an incentive to switch from car travel to bus travel would only work in an area where there is an opportunity for people to switch to buses.

In many instances, namely entering urban areas and along major commuter routes, bus services exist, and so pricing on those roads will have a positive effect on the use of public transport for two reasons. First, the cost of driving increases relative to the alternative pricing (provided that the new toll does not excessively drive up the cost of providing bus services, though this can be avoided by granting exemptions to buses) and second, because journey times will become faster and more reliable for buses with relieved congestion. This may further improve with bus-only lanes or similar developments. For some drivers, the improved journey times for their trip may be worth paying the extra toll, but certainly for others, taking the bus will become more attractive.

For other areas, though, namely those areas where nationwide road pricing would only consist of an environmental charge, as there is little congestion, alternatives to long car trips do not exist, or at least not to the same extent. Thus, in the absence of substitutes, the desired change in behaviour will not materialise as much, but drivers may still be worse off. It is possible that pricing roads in these areas will increase demand for alternative modes of transport, thus giving companies an incentive to expand routes to those areas, but the increase in demand certainly will not be worth the cost of expanding to all areas. The absence of substitutes in areas like this will give drivers the incentive not to make some trips, but as mentioned before, this may not be a large improvement upon current fuel duties.

With the huge costs of implementing a system that would make charging these areas possible, it once again becomes questionable whether a satellite system provides optimal value for money. The DSRC systems, though, give policymakers the ability to implement pricing systems in areas like congested motorways and urban areas where substitutes are available and road pricing is more of a cost-effective tool of an integrated transport solution.

In short, there are few advantages to be obtained by investing in a satellite-based system in terms of changing the behaviour of drivers.

How will the system operate?

In ‘Implementing Road Pricing’ all scenarios (except for the scenario of independent urban charging scenarios, also discussed below) involve operation within a national framework, where the responsibilities of the system are divided by function, that is:

- An On Road Service Provider (ORSP) handles charging on the road.
- A Data Clearing Organisation (DCO) processes data from many ORSPs, changing a car’s information into an account number.
- The DCO sends account data to the appropriate Payment Service Provider (PSP).

There are certain benefits of economies of scale and interoperability of this model, but as mentioned in section 4.2 of the Procurement Funding Report part of ‘Implement Road Pricing’, there may be value for money in integrating the PSP and DCO to promote competition, as the differentiation of products and services by price and quality is essential for competition and may be difficult with these functions divided (which is noted in section 2.2 of the Procurement and Funding Report). Furthermore, with independent urban schemes, there can also be value in integrating the ORSP as well so as to enable easier private financing and risk transfer. An optimal system, then, should have good prospects for risk transfer, competition (through price/quality differentiation) and interoperability.

As mentioned earlier, integrating functions gives a better opportunity for risk transfer, and thus, for a private operator to become involved with a road. Allowing the government to transfer risks, particularly in capital-intensive projects like these, ensures better value for money as risks are handled by those more suited to deal with them. Such success has been a characteristic of past DBFO deals. As those deals were intended to build experience for future toll roads, those gains can be utilised by a properly designed road-pricing framework.

As mentioned in the study, the prospects for competition in the national framework between different providers of different functions (ORSP, DCO, PSPs) are limited. Competition in a different sense, though, by *facility*, may have more potential. As functions can be integrated in the independent urban schemes, with similar integration, urban schemes or different tolled roads can then compete with each other, both through quality of the road as well as road price, and also with other modes of transportation. Allowing price and quality to be set for a particular road is crucial for two reasons - appropriately covering infrastructure and congestion costs on that road, and for appropriately competing for local commuters. Thus, a facility-based system can give private operators the incentive to reduce the costs of integrated functions and maintain high-quality roads. This, too, will build upon the experience of UK road operators in past DBFO contracts.

Having a private operator of the entire national road network or even of certain portions of it, however, might not yield the same benefits of competition. While it may make interoperability easier, having control over various substitute roads may yield too much monopoly power. While it is true, like other roads with highly inelastic demand, that the operators could be regulated, this would increase the costs of regulation, and not be as optimal as having more operators competing.

It is even possible to maintain interoperability between charging systems even with different private operators. As in Chicago, the installation of a desired electronic tolling system (likely a common DSRC operator) can be a condition of a concession agreement. In addition, as long as monopoly power is properly limited, either through competition, price regulation, or Concurrent Real and Shadow Tolling (see above), improper traffic diversion should be minimal.

Private investment

Of course, one of the main benefits of private sector involvement is access to private capital. The advantage of road pricing over traditional shadow-toll DBFO contracts is that the government need not use any tax revenue, as toll revenues can go to the private operator. In deciding on how to implement a national road pricing system, there are important tradeoffs to face. If charging is nationwide (satellite based), it is easier to reduce other centrally collected taxes (i.e. fuel duty and VED), though as discussed earlier, this may distort incentives, and may not be worth the other costs of implementation. Furthermore, if tolls are higher in some areas than others, then lowering the fuel duty for all motorists may be seen as redistribution. With a project based system, on the other hand, it will be necessary to use revenues from a particular toll road (under private financing, to use a concession payment) to benefit that particular area, just as London congestion charge tolls have been used to finance London transport. Indeed, the $3.86 billion concession payment to the State of Indiana for the lease of the Indiana toll road has gone towards a redevelopment of the state’s road network. Still, under this system, fuel duties and VEDs can be reduced to the extent that the central government does not need to spend as much money on road financing. In other words, the £140 billion in road widening and new road construction that is already planned in the UK can be funded through an alternative system. Depending on the scheme implemented, private funds could be used not only to build one of these new roads, but they could also be paid to the government upfront or through revenue sharing.

More importantly, though, as noted in the 'Implementing Road Pricing' (Procurement, 4.5), a full national rollout may be too large and expensive for a PPP or PFI deal, and may require substantial central government funding. This puts billions of pounds of tax revenue or debt at risk, and, along with the necessary improvements in technology, could make implementing any scheme before 2015 impossible.

In short, a facility-based framework seems to provide the best allocation of incentives and risks. Although it does not necessarily involve using expensive new technology, it does offer opportunities for innovation in providing quality roads, and will likely lead to new developments within that framework, as with electronic tolling and variable pricing.). Just as taxpayers got better value for money with shadow-tolled DBFO roads, future road users will get better value for money with the roads they pay for, thanks to higher quality and lower congestion. The benefits to road users, investors, and the nation's transport network should not be overlooked.

Conclusion

While this paper is by no means the end of the investigation into different avenues of road pricing, based on this analysis it would be worthwhile exploring a road pricing policy based on:

- A common system of DSRC technology.
- Electronic tolling of congested motorways and urban roads.
- Private financing and operation of new tolling systems on existing roads, new roads and premium lanes on congested roads.
- Using funds raised through concession payments and revenue sharing to replace burdensome fuel duties and VED where possible, and re-investing in public transport or necessary road improvements in local areas.

Eventually, there may be benefits from the next generation of technology that make it easier to unite charging schemes across the nation. However, policymakers should also consider other means aimed at the same ends. In particular, pricing roads on a project-to-project basis is a more surgical tool for solving individual congestion problems, and would provide a way for the UK to build on practical experience. The implementation would be more straightforward and the benefits are easier to predict. If anything, the advent of toll roads throughout the UK may provide a stepping-stone towards integrating these charges. Indeed, public acceptance of road pricing is likely to increase when more travellers experience the benefits of congestion-free journeys. Perhaps the greatest benefit, however, of a more manageable strategy is that it can be put into action in a matter of months, rather than nearly a decade. With congestion increasing year on year, further delay will prove very costly.

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