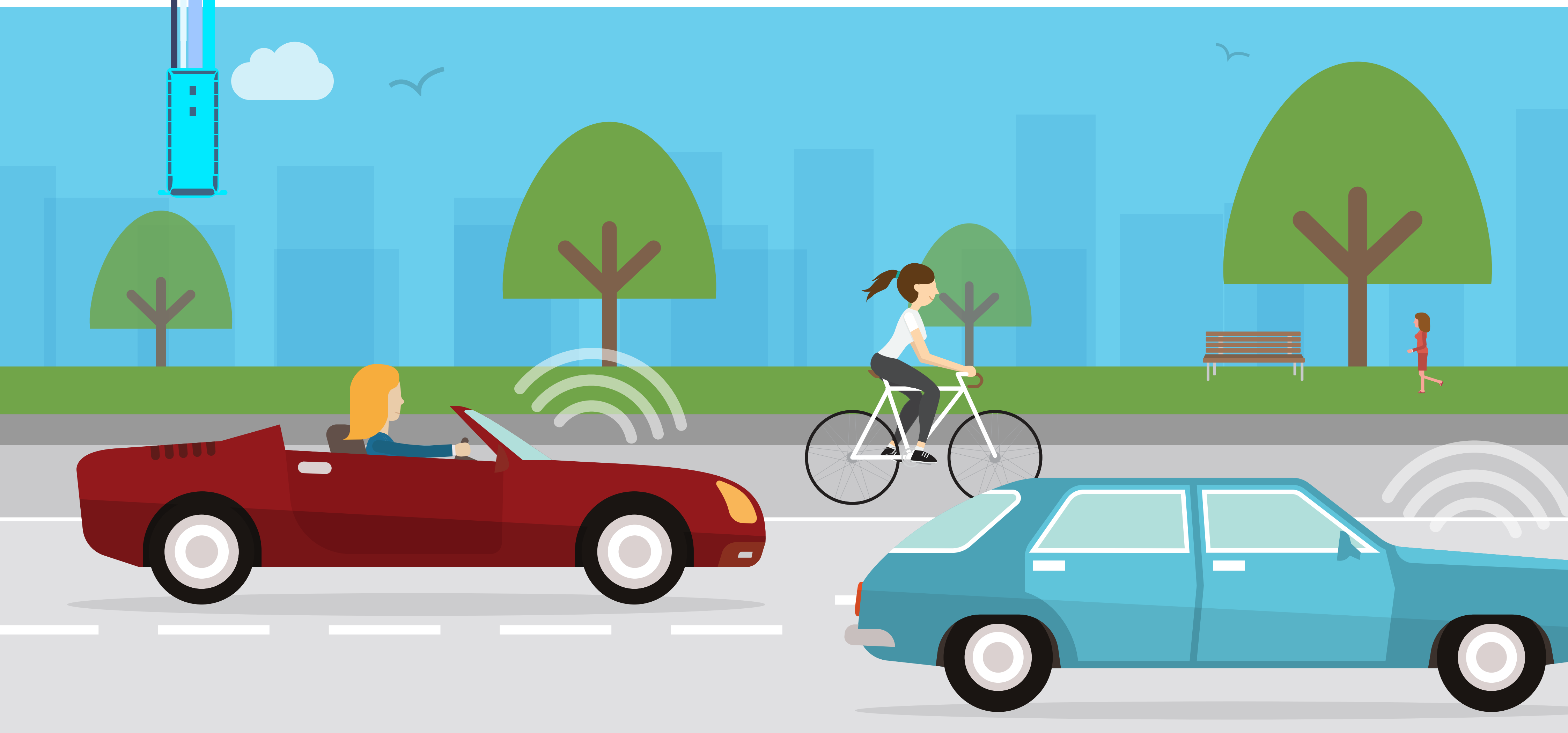
WOLFSON ECONOMICS PRIZE MMXVII

Policy Exchange

Pricing for Prosperity

Volterra JACOBS

WOLFSON ECONOMICS PRIZE MMXVII FINALIST



WOLFSON
ECONOMICS PRIZE
MMXVII

Volterra Jacobs

Pricing For Prosperity

Paul Buchanan, the spokesperson of Volterra and Jacobs', is an economist specialising in the transport sector. Paul has led many major project appraisals including Jubilee Line Extension and Crossrail. He has extensive overseas experience. Paul led the development of Wider Economic Benefits for Crossrail from 2002 to 2005, subsequently incorporated into DfT guidance. He is a Partner at Volterra.

Policy Exchange

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The Wolfson Economic Prize invites entrants from around the world and all sorts of backgrounds to propose original, well-argued and informed solutions to big national challenges. The aim is to bring forward fresh thinking to help people, governments and businesses develop practical policies.

This year the prize addresses an issue at the heart of every country's economic future: road infrastructure, and

how can we pay for better, safer, more reliable roads in a way that is fair to road users and good for the economy and the environment?

The way cars are powered, driven and owned is being revolutionised. Soon a world of cleaner, automated vehicles will arrive and old annual charges and petrol taxes will no longer work. A new kind of driving will take a new kind of road and a new kind of funding – ideas needed not just in Britain but around the world.

The five shortlisted submissions – of which this is one – show that it is possible to come up with potential answers that can help road users, improve safety, protect the environment, and support our economy.

Contents

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Executive Summary

Our roads are congested

Roads are the arteries of economic activity: connecting labour to jobs, goods to markets and people to places. The vast majority of passenger and freight trips are on our roads. Over the last 50 years, traffic has risen by almost 400% but road mileage has increased by only 30%. The result has been a significant growth in congestion and its severity, increased unreliability in terms of predicting journey times as well as a rapid decline in air quality.

… and expensive!

We pay high costs for using our congested roads. Through fuel duty and Vehicle Excise Duty (VED), British drivers pay just over £30bn a year to HM Treasury of which less than 25% is actually spent on our roads. Not only are journey speeds declining but so is the condition of our road network with an estimated 13 years' backlog of essential maintenance. Today there is no link between what drivers pay and what is spent on the road network.

Why?

Largely because we pay for roads in the wrong way and there is no connection between the traffic that roads handle and the money that flows to highway authorities. For the highway authorities, roads are liabilities that cost money, not assets that generate a return so they are a low priority in a world of limited resources and competing demands. The taxes paid by motorists are either "fixed cost" like VED or "average cost" like fuel duties. They are designed to raise funds for government, not to make roads work more efficiently. Marginal cost payments, where you pay for the roads that you use and the time at which you use them, can deliver more efficient outcomes.

How?

By making the price signals clear to road users, helping them to make better choices on timing, routeing and which mode to use. A large part of the problem is that current price signals are ineffective at matching demand and supply.

What are we proposing?

The Pricing for Prosperity (P4P) solution will provide a time and money quote for any journey and information on alternative routes, timing and modes and to what extent this will change costs. If the quote is accepted, then the highway authority has the responsibility to deliver. Unexpected delays will mean financial compensation to drivers. After each journey, the driver will receive a summary of the actual journey, route, time and cost.

Within P4P there will be a single charge comprising three elements:

- A congestion charge – which will rise in line with, and hence reduce, congestion. No congestion - no congestion charge. All of the money raised will be invested in improving the overall transport network;
- An environmental charge – the adverse effects of road use, such as noise and air pollution, will be paid for by drivers and spent on mitigating those adverse effects. For clean and quiet vehicles the cost could be zero; and
- A maintenance charge – which will cover day-to-day maintenance and operational costs and ensure all roads are maintained to a high and safe standard.
- All charges will be set and monitored by an independent regulator which will also be responsible for ensuring highway authorities are efficient and cost effective in the delivery of their operations.

Present ....


LIVE BUS ARRIVALS
BUS 1: 12 MIN
BUS 2: 14 MIN
BUS 3: 36 MIN
BUS STOP
PETROL
£1.20
£1.40

Will it work?

Yes, all the evidence from cities such as Singapore, London and Stockholm and toll roads worldwide, shows road pricing to be highly effective at reducing congestion and providing road users with more reliable journeys. It is notable that early scepticism about road pricing when introduced is replaced by widespread support once its benefits become apparent. The P4P solution will be effective at reducing congestion, providing reliable journey times, protecting privacy and highly efficient in terms of cost of operation.

What will happen?

Better price signals will help drivers avoid congestion by re-routeing, re-timing or changing mode or destination. Journeys will take less time and will be much more reliable. The P4P price signals will also encourage the use of more environmentally friendly vehicles by charging for emissions. The price signals to drivers will be clearer. Not only will P4P change demand on the roads it will also generate significant new investment to increase capacity, improve driver behaviour and mitigate external costs.

Is it fair?

Our analysis suggests that around 90% of private road users will either be financially better off or no worse off than at present and most of those paying more will be higher income road users. Polluting and infrastructure-damaging freight vehicles will pay more but will benefit from more reliable and faster journeys and the vast majority of cleaner private cars will pay less. We will introduce a vehicle scrappage scheme to encourage the replacement of older more polluting vehicles and enhance bus services in congested urban areas to provide choice in advance of P4P commencing. Bus users will, in fact, be major beneficiaries as journeys become faster and more reliable. Those in rural areas, even though they drive more than average, will pay less than those in urban areas as there will be no congestion charge element.

Will everyone know where I have driven?

Not if you do not want them to. Blockchain technology enables all journeys and payments to be made anonymously if desired and there will be no central government database of people’s journeys.

Sounds good for the driver, what about the economy?

Simply by eliminating the majority of delays, P4P will deliver £160 billion of time savings over a 30 year period (present value discounted). In addition, reliability benefits are conservatively estimated at a further £40bn. There is a direct reduction of £60bn in business costs from faster journeys. There is also a £37bn reduction in commuting costs resulting in wider, deeper and more efficient labour markets as well as improved reliability. If HM Treasury were to collect 40% of those savings in taxes, there would be an additional £38bn in tax revenues. That is in excess of the £21bn net cost to government of the scheme, relative to a do nothing scenario,

Conclusions

Now is the time for road pricing. Our roads are in a poor state and clearly impacting on business performance and quality of life. The move away from carbon fuels and the introduction of connected and autonomous vehicles will result in a loss of government revenues, whilst at the same time delivering a significant increase in road use. ‘Do nothing’ is not an option; road pricing with modern technology offers a long-term solution to the UK’s uncompetitive transport infrastructure by providing more reliable and faster journeys.

Future with Pricing for Prosperity

1. The state we are in

The car has been the dominant passenger mode in UK transport since the late 1950s when it overtook other road modes (largely bus) as the main means of travel. Prior to this, as shown in Figure 1, rail had been dominant since the second half of the 19th century, but the lower cost and greater flexibility of first buses and then cars provided a more attractive alternative.

To understand how well UK roads perform a comparison is required with other countries. Figure 2 shows the total highway provision across selected countries per square kilometre of land and per one million people. Country size is a key determinant of highway provision, but population, wealth and car ownership are also important. Overall, the UK scores poorly compared to the European countries in the sample.

The main determinants of the road density measure are population density and car mode share. In general, the larger countries tend to have lower road kilometres per square kilometre because their population densities are lower. Thus Australia and Canada have low results for this measure despite having high car mode shares.

Figure 3 shows that the number of kilometres of road per square kilometre of land is heavily dependent upon population density. It also suggests that the UK (red dot in Figure 3) is undersupplied with roads for a country with its level of population density.

Figure 4 displays total road kilometres in the UK from 1951 to 2014 alongside total vehicle kilometres over the same period. Since 1951 vehicle kilometres have increased by 765%, an average annual increase of 3.4%, but road length has risen by only 33%. The difference between those two numbers is the primary reason for higher congestion.

Figure 1: UK transport mode shares (%) since 1952

Source: Department for Transport, Statistics

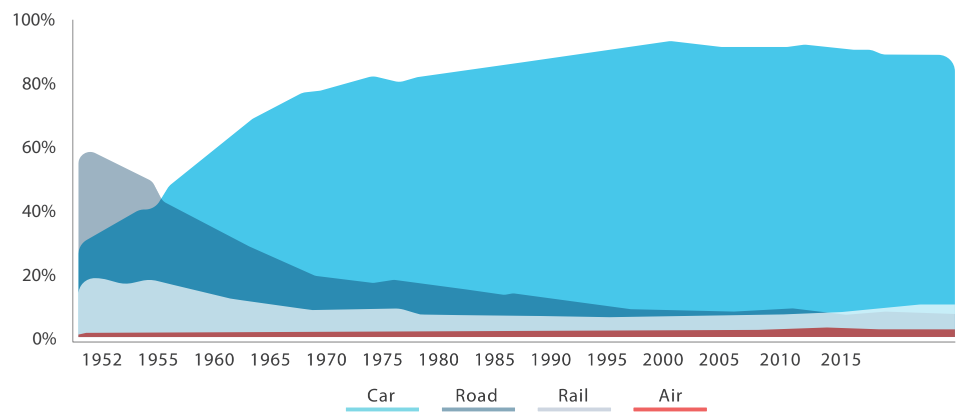


Figure 2: Road provision per sq. km of land compared with people per sq. km of land

Source: CIA World FactBook, 2017

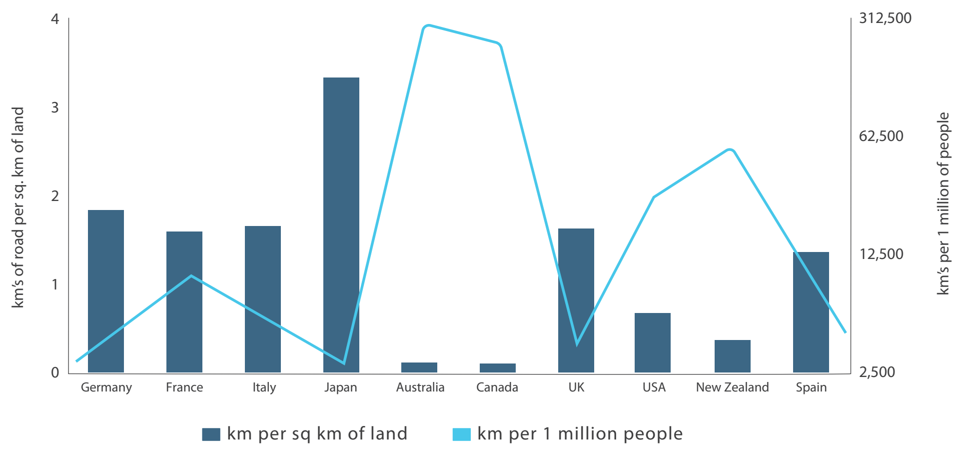


Figure 3: Total road provision per square kilometre of land and per million of population, per country

Source: CIA, World FactBook, 2017

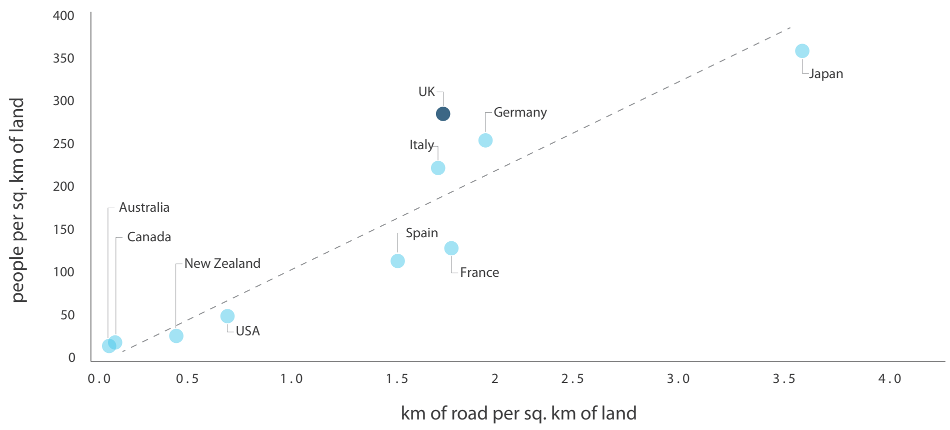
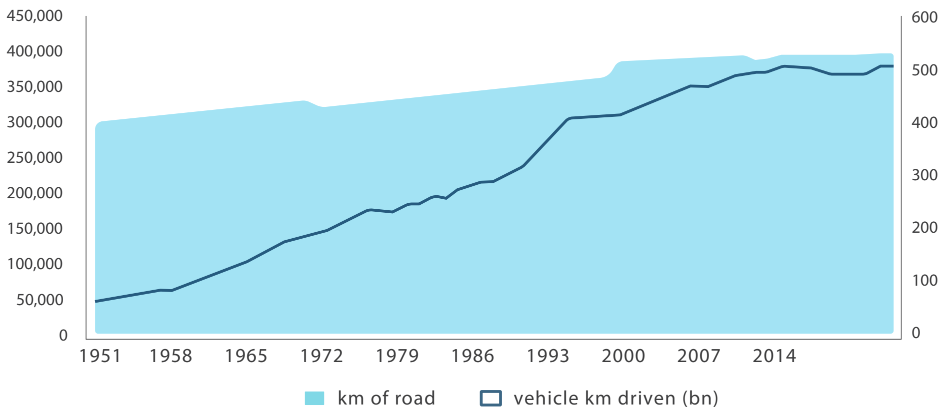


Figure 4: Trends in UK road provision (kilometres) and vehicle kilometres - 1951 to 2016

Source: DfT statistics



In more recent years, growth in vehicle mileage has been lower. Between 1995 and 2005, the average annual increase was only 1.4%, an overall increase of 15%. Since 2005, vehicle kilometres have only increased by 3.2%, with an average annual increase of 0.2%. However, there has been an upturn in growth as the economy has come out of the recent recession. Road length has plateaued since 1995; the increase in road kilometres from 1995 to 2015 was only 2.4%. However, virtually all of this growth has been of minor local roads serving new developments. In the last ten years, the length of all major roads in Great Britain (motorways and 'A' roads) has increased by just 115 miles or 0.4%.

Growth in car usage has reduced in recent years. The "peak car" phenomenon suggests that this is largely due to behavioural change among Millennials, but it may be much simpler than that. Figure 5 overleaf shows that total motoring costs (including vehicle purchasing costs) have fallen in real terms. However, there has clearly been a large increase in running costs of driving with higher fuel prices (and fuel taxes) and more expensive insurance, especially for young people. At the same time, the increase in congestion caused by the mismatch between demand and supply has made driving slower and more unreliable. It appears that the increase in marginal costs has led to a change in behaviour reinforcing the importance of marginal cost pricing.

It is difficult to obtain comparable congestion information between countries, but TomTom and INRIX provide some useful data. TomTom data is focussed on congestion levels in cities and uses its database to determine levels of congestion in 295 cities around the world. In this dataset, congestion is measured using the percentage increase in travel time compared to travel times at free flow speeds.

The TomTom Traffic Index[1] data, presented in Figure 6, shows that the UK performs relatively poorly compared to other countries. For example, in the UK the number of cities with congestion over 20% (i.e. those where average all-day journey times are 20% higher than free flow travel times - congestion levels in the peak are far higher) is 23, the same as in the United States, a much larger country with far more cities. As shown in Figure 6, in terms of all day congestion levels the UK tops the index list at 29%, while the United States has the lowest average congestion level at 18%.

The INRIX[2] (2016) congestion analysis takes a similar city-focussed approach, shown in Figure 7. This analysis looks at European cities with populations over 250,000. An impact factor is used as the measure of congestion (i.e. how large the impact is on traffic). This impact is weighted by population so that countries that have more cities are not over-represented. INRIX also provides forecasts of the predicted economic cost of congestion over a 10-year period, based on time lost due to traffic. Once again the UK emerges as the most congested, with the highest absolute and population weighted impact factors, as well as the highest economic cost of congestion.

Figure 5: Changes in motoring running costs in the UK

Source: DfT Statistics, Table TSGB1307

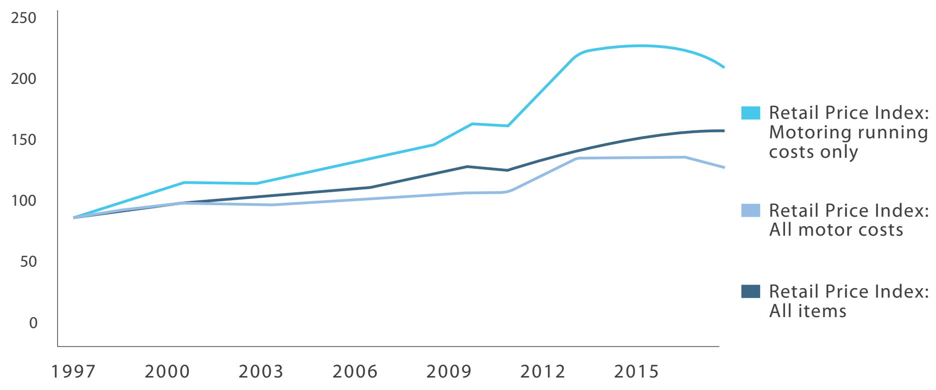
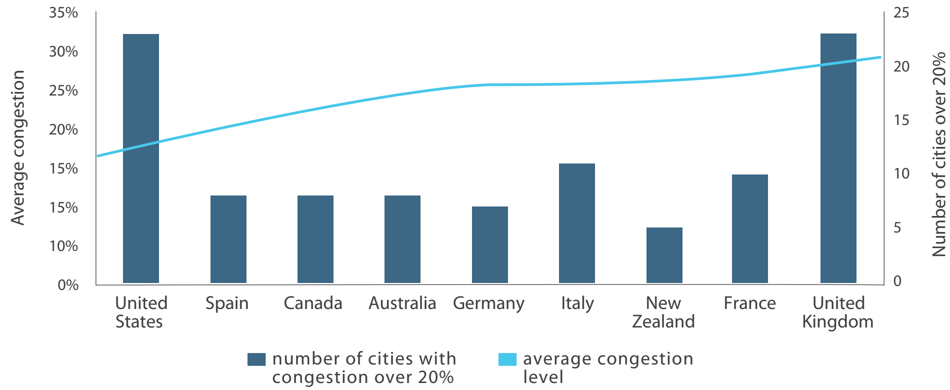


Figure 6: Congestion, by country

Source: TomTom Traffic Index, 2016



[1]TomTom Traffic Index, 2016, http://www.tomtom.com/en_gb/trafficindex/list?citySize=LARGE&continent=ALL&country=ALL
[2]INRIX, (2016), Europe's Traffic Hotspots – measuring the impact of congestion in Europe

Figure 7: Impact and cost of congestion, by country

Source: INRIX Roadway Analytics[13]

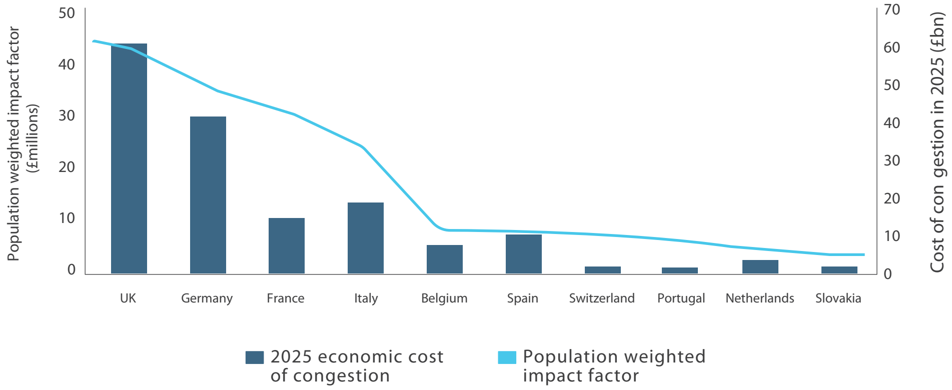
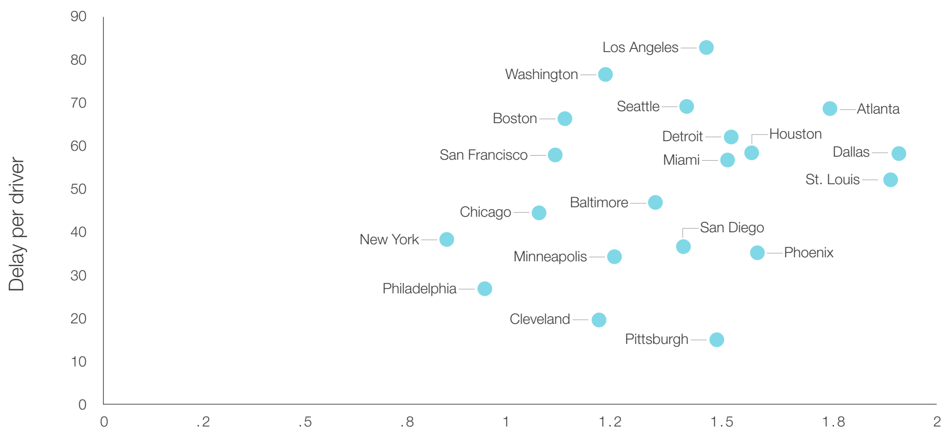


Figure 8: Comparison of traffic lane miles and delay for 20 biggest US cities

Source: Urban Transport Monitor, 1999



Summary

The UK is a densely populated island with lower road provision than most European comparators. International comparisons of congestion suggest that our roads are more congested than those in comparable countries. The direction of causation can be difficult to determine. Figure 8 shows through a comparison of US cities, the more traffic lane miles provided per capita, the higher the level of delay experienced by users. Building more roads is certainly no guarantee of faster travel.

Regarding finances, the government makes a substantial net surplus from the road sector. Income from fuel taxes (c. £27bn a year) and VED, (c. £5.5bn a year) combine to make £32.5 billion a year. This significantly exceeds the costs of maintaining and operating UK highways which currently stands at approximately £8bn a year. UK motorists are paying more but doing so in a way which does not encourage them to make more efficient choices on when to drive and what route to take, let alone encouraging a change in mode. In addition, roads are seen by highways authorities as a liability rather than an asset as they incur costs and generate no revenue and hence are low priorities for investment. P4P will turn roads into revenue generating assets allowing highway authorities to invest in maintaining and enhancing their transport networks.

[13]INRIX Roadway Analytics (2016), 'Congestion At The UK's Worst Traffic Hotspots To Cost Drivers £62 Billion Over The Next Decade', http://inrix.com/press-releases/inrix-reveals-congestion-at-the-uks-worst-traffic hotspots-to-cost-drivers-62-billion-over-the-next-decade/

2. Potential solutions, barriers and road pricing examples

2.1 Matching demand and supply of road capacity

It is clear that in many parts of the UK there is a mismatch in the supply of and demand for road capacity. We therefore need to build more road capacity without generating too much of an increase in demand, restrict demand in ways which do not harm the economy or the environment, or probably a combination of both. The main policy options for doing this are described in Table 1.

2.2 What are the barriers to change?

It is always easier to maintain the status quo than to change something, no matter how poor the current position or how effective the proposed solution. Road pricing has been proposed many times in the UK only to fall at the hurdle of public support. The main barriers include:

- All car drivers will be affected and some (albeit only a minority) will no doubt be financially worse off. However, in terms of generalised cost (the sum of the monetary and time costs of a journey), all will be better off with faster journeys offsetting any higher financial costs;
- HM Treasury may not welcome a system which hypothecates funds, even to a sector as important as transport, although VED has recently been hypothecated;
- Motorists don't trust politicians when it comes to charging, but are in principle supportive of the idea of road pricing. The AA's Populous Survey (2017) found that 46% of drivers were in favour of replacing fuel duty and VED with a system based on when, where and how far you travel, compared to 33% who did not. However, 75% said they did not trust the government to deliver if promises were made to reduce fuel duty and VED on the introduction of road pricing;
- There are distributional impacts of a pricing policy, although often not the ones that people perceive. The biggest beneficiaries tend to be those on lower incomes travelling by bus who get faster journeys. The other main beneficiaries are those who drive less than average, who tend to also come from lower and medium income groups. Those who drive high mileages in peak periods may pay more but will gain benefits in terms of time savings; and
- The road management system and/or operator will know where vehicles are located, and perhaps where they are heading and when. This will generate an enormous amount of trip data containing potentially sensitive personal information. This raises issues of privacy, even if no more so than the ability to track people's movements via mobile phones, apps, CCTV, smartcards, etc. The issue of privacy is a wider, societal issue, but there are technological solutions which enable payment whilst retaining anonymity.

Table 1: Road pricing policy options

Option	Description
Raise fuel tax to restrict demand	Fuel duty is a system of broadly charging by distance travelled but it has no long-term future as a traffic management tool. This is a blunt tool, as fuel duty is not location specific. As the country moves away from carbon fuels for road transport, it will become less effective at managing demand and raising revenue. It does, however, have the advantage of being an existing tax with low collection costs and one that is difficult to avoid.
Rationing car use	In this option, every person gets an allowance of driving an agreed number of kilometres a year. This is seen as a "fair" or equitable system, in that everyone receives the same allowance. People who don't use their allowance might be able to sell the unused portion to other drivers resulting in some income redistribution impacts. However, the system is ineffective at dealing with congestion; indeed it might make congestion worse. Similar problems arise from the use of odd/even number plates on alternate days and it can be avoided through owning multiple cars.
Pricing/restricting parking	Parking charges and restrictions are a good way of managing traffic demand to specific locations, but they are not effective at dealing with general congestion, for example, on motorways.
Increase road building	New roads can be built and add to existing road capacity. This is generally expensive especially in urban areas, unpopular and exacerbates environmental concerns. The mass protests against road building of the 1980s made large-scale road building increasingly difficult. Importantly, building more roads may still not deliver the desired outcome of alleviating congestion. Although there are still a large number of road capacity schemes that will improve traffic flow and safety that can be usefully progressed as well as filling in missing links in the strategic network (e.g. Oxford to Cambridge), history suggests that spare capacity is rapidly filled by trip generation. Hence building new roads alone is not an easy, cheap or popular solution to resolving traffic congestion.
Technological change	Much hope is placed on the role of technology in delivering higher capacity on roads. Connected and/or Autonomous Vehicles (CAVs) operating closer together can certainly increase capacity and reduce accidents, but have the potential to also increase congestion if left unchecked. It is difficult currently to have any real insights about the scale of those impacts.
Road pricing	Pricing can potentially be a policy option for: • financing the network; • ensuring that the external costs of road use are mitigated; • managing the network, especially dealing with congestion arising from peak demand levels; and • incentivising highway authorities to improve the network and the efficiency of their operations.

Against this backdrop of policy inertia there are also positive reasons to think that the barriers to change are lower now than previously:

- People are accustomed to treating car use as a service. Car clubs, trip sharing apps and Uber Pool are all examples of mobility services and people are much more amenable to those systems in the new "sharing economy";
- Uber has demonstrated the attraction of a system that not only picks you up quickly but informs you of the price and journey time in advance. Moving to a similar user-friendly system for road travel will put it on a par with rail and air transport;
- Relevant technology has advanced sufficiently to make efficient road charging deliverable. The congestion charge in London spends over 50% on administrative costs; new technology means that this can be done for less than 10% now;
- Government tax revenues from road use will decline significantly in the future as improved fuel efficiency and electrically powered vehicles reduce petrol and diesel consumption. Government will need to find additional alternative revenue sources; and
- Growing concern about air quality and increased use of more sustainable travel means there is less support for unfettered use of private road transport and more support for charging for negative externalities such as emissions

Figure 9: Percentage of people who would vote "yes" in a referendum on road pricing, excluding "don't know"

Source: Eliasson J. 2014

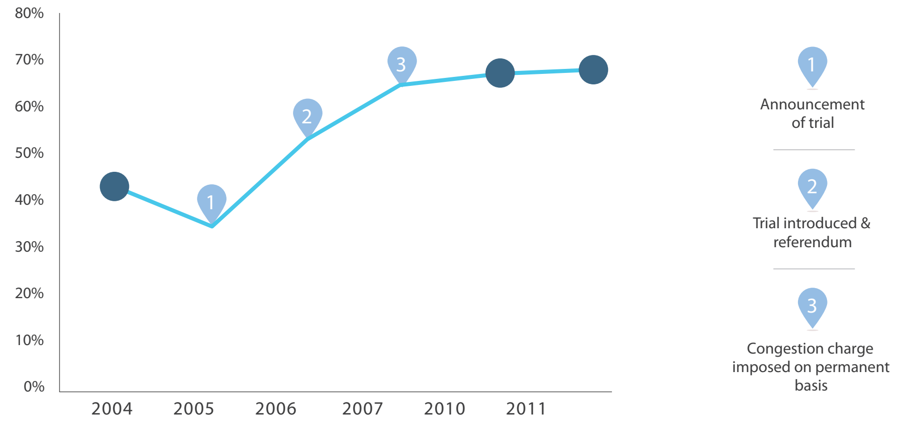
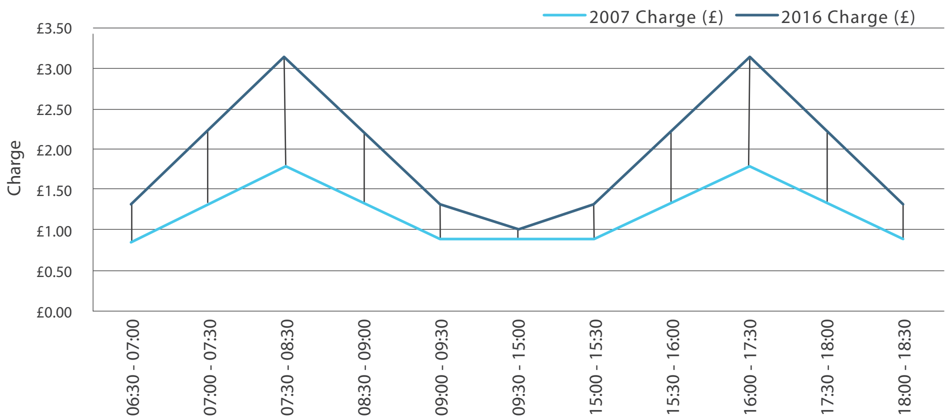


Figure 10: Original charges (2007) and revised charges introduced in 2016 by time of day

Source: Eliasson J, 2014)



2.3 Road pricing: case studies

2.3.1 Introduction

This section considers three examples of road pricing in three different countries: the Electronic Road Pricing charge in Singapore, the congestion charge in Stockholm and the London Congestion Charge. Each was implemented under very different political backdrops and each was initially unpopular with the public, who had doubts over how effective they could be. Since implementation, all three examples have not only reduced congestion in their respective cities but also now enjoy majority public support[4,5].

2.3.2 Stockholm

The scheme in Stockholm was introduced as a seven-month trial and then residents were asked to vote whether to retain the scheme. Initially, public support was low, however, when drivers started to see the benefits of road pricing support gradually grew as shown in Figure 9.

The charge applies on weekdays and is a cordon scheme. Users pay a single charge for entering the cordon regardless of how long the vehicle stays or how far it is driven within the zone. Figure 10 shows the charges for different times of day, rising during the morning and evening peaks.

[4]J. Walker (2011), Acceptability of road pricing, RAC Foundation

[5]Eliasson J. (2014), The Stockholm congestion charge: An overview, Centre for Transport Studies: Stockholm

Traffic and travel times

As a result of the charge, queuing fell by 30-50% and there was a reduction in traffic of 22%[6]. In spite of population, economic and car ownership growth, traffic levels have remained relatively constant since the introduction of the charge, with charges only rising in the peaks.

Vehicle Switch

The Stockholm congestion charge has not only been a mechanism for reducing congestion but also a way of tackling pollution. This was evident from the exemption made for cars using alternative fuels. The share of alternative fuelled cars in Stockholm increased from 3% in 2006 to 15% in 2009. The exemption was removed in 2012 because of a debate over exactly what constituted a 'greener car'. Nonetheless, it showed that a charging system favouring less polluting cars is an effective way of changing fleet composition.

2.3.3 Singapore Electronic Road Pricing

In order to tackle the growing congestion issue, a road pricing system which would manage the demand for road space was introduced. Initially it was the Area License Scheme (ALS) and evolved in 1998 to become the ERP scheme. It was first introduced in 1975 as a cordon scheme managing traffic into the central business district (CBD). Originally just applying to the morning peak it was later extended to all hours with differential peak and off-peak pricing. The ERP is an electronic version of the ALS in which price can be varied at different times and places according to traffic conditions. From the user perspective, all they need is to have a smart card on their car dashboard, charges are deducted automatically.

[6] Eliasson J. (2014), The Stockholm congestion charge: An overview, Centre for Transport Studies: Stockholm

This approach still fails to inform drivers of alternative modes, routes or travel times and how charges would change in response to those. This is something our proposed scheme addresses by detailing cheaper alternative times, routes and modes. A new Global Navigation Satellite System (GNSS)-based ERP system, which uses broadly similar technology to P4P will be operational from 2020.

The most important difference between the ALS and ERP was the ability of the ERP to set the price to whatever it needed to be in order for traffic to constantly be running at the desired speeds.

Acceptability

To increase acceptability, there were various adjustments made to the vehicle tax structure. There was a concern the ERP could be viewed as purely an extra revenue stream for the authorities. To prove the ERP was a genuine attempt at better managing road usage some of the upfront taxes of vehicle taxes, registration fees, additional registration fees and road taxes were reduced.

ERP impacts and benefits

Due to the ERP replacing an existing road pricing scheme, the ALS, the impact upon traffic levels would not be expected to be as high as other schemes. In spite of this, the ERP still led to an immediate 15% reduction in traffic entering the zone and in 2015 traffic was still below pre-1975 levels as seen in Figure 11. Even more remarkable was the 34% drop in repeat trips into the zone, a result of the removal of the day pass. Drivers now have to plan their journeys to avoid re-entering the zone and incurring additional cost.

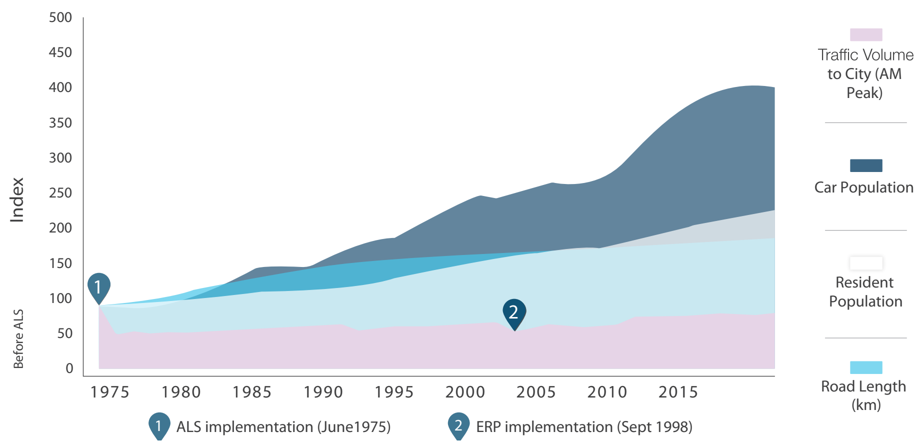
While the ERP as is not a real-time dynamic charging system, traffic flows are regularly reviewed and charging levels are adjusted every few months if needed.

This means that the Singapore Land Transport Authority (LTA) can, within reason, deliver average target journey times they want by increasing the price whenever traffic speeds get too low. This is why the LTA have consistently met their target of keeping speeds between 20 and 30 kph on CBD roads.

This is of particular relevance to our proposed scheme because it aims to have a far more advanced version of the ERP. The ERP has a price based upon congestion levels to manage road demand within a cordon. Our scheme will have a separate price tailored to managing the demand for each specific road link in the country which potential changes in real time. This produces a far more effective method for managing congestion whereby on every road the desired speed or journey time can be achieved.

Figure 11: Effect of road pricing on traffic volume to the city. Index, 1975 pre-ALS = 100

Source: Menon & Loh, 2015[7]



[8]J. Walker (2011), Acceptability of road pricing, RAC Foundation

2.3.4 London Congestion Charge

The London Congestion Charge (LCC) was part of Ken Livingstone's manifesto when campaigning to be the first London Mayor. Following his election in 2000, the LCC was officially implemented in 2003 without referendum or trial.

The LCC is a cordon-based scheme covering an area of approximately 22 square kilometres within central London. When a vehicle drives into the zone, a charge must be paid which relies upon self-declaration. Automatic Number Plate Recognition (ANPR) cameras take a note of the number plate and if that number plate is not associated with a valid payment transaction, the owner of the car is fined.

The LCC has a number of exemptions/discounts covering:

- Buses;
- Taxis & minicabs;
- Disabled people;
- Residents; and
- Low-polluting vehicles.

As a result of these exemptions, only 30% of vehicles crossing the central London cordon are actually liable to pay the charge in full. The scheme also suffers from very high collection costs, 51% of the c£120m annual revenues. In 2002, before the charge, only 40% were in support. Following the introduction of the charge this rose to 59%[8].

Impacts

Following its introduction, the number of chargeable vehicles entering the zone decreased by 31%. It was estimated that of those who no longer drove into the LCC zone, 60% switched to public transport and 30% diverted around the zone, with the remainder making other changes (including changing trip time).

As a result, congestion within the cordon fell by 26%. The impact on congestion in more recent years has reduced as Transport for London (TfL) has re-allocated road space to cyclists and pedestrians.

2.3.5 Lessons from the three case studies

There are five key conclusions to be drawn from the case studies:

Pricing Works – all of the case studies have been effective tools in managing demand. Traffic has fallen initially by 20-35%, and importantly the flexibility of a price-based system means that traffic can be kept at any desired level.

Public Acceptability – the public find it easy to understand the financial costs of road pricing but difficult to believe the impacts on journey times and reliability. They are so used to peak period congestion that they have difficulty perceiving how the road network could ever operate at free flow speeds in the peak. The case studies show that once road users see the benefits of road pricing it becomes acceptable.

Cordon charging – cordon charging schemes are a less effective form of charging than distance or link based schemes. They charge to enter a defined area but not for the distance driven, nor the costs imposed on others. If cordons can deliver 20-30% reductions in user demand, then pricing across a whole network could do it more efficiently i.e. at a lower price.

Charging for environment and maintenance costs – some effort is made in all of the three examples to include environmental costs within the charging system. This is good politics as well as good economics. Those charges both changed driver behaviour and choices of vehicles and fuels.

Revenue generating – while not the primary reason why the schemes have been the implemented each of the cities uses the funds generated by them to invest in improved transport provision across their cities.

3. Our Solution

3.1 Introduction

This chapter sets out the main elements of our solution from the perspective of users, the government, the regulator (the existing Office of Rail and Road), highways authorities and the private sector operators of the scheme.

Our solution very simply charges motorists for every mile they drive on the road network. That charge consists of three elements: a) road maintenance and operation, b) environmental and c) congestion. Not all of these will necessarily apply to each journey.

It encompasses a holistic system which:

- Can price congested parts of the network whilst also funding future investment so that road infrastructure can be improved and charges reduced in the future;
- Will be cheaper and faster for a large majority of road users;
- Ensures that the road sector pays for itself, covering its maintenance, congestion and environmental costs in a sustainable long-term solution;
- Is infinitely flexible, cheaper to implement and operate than existing tolling systems;
- Can adapt to technological change at different rates and scales of change, for example accommodating autonomous vehicles and Mobility as a Service concepts;
- Gives drivers effective performance-related charges, automatic price reductions and/or compensation if things go wrong; and Offers complete anonymity if desired.

Once the scheme has received Parliamentary approval, we envision that it will be rolled out within 18 months with a lot of the preparatory work taking place beforehand. This work will include the regulator advising on the level of charging, simplifying the number of highway/transport authorities and trialling the equipment and software to be used. As VED and fuel duty levels are UK wide taxes it is proposed that P4P will operate throughout the UK.

3.2 The user's perspective

Imagine that it is 2020 and you are planning a journey from your home. You pick your phone and access the intuitive P4P app. You tell the app your destination and preferred departure and arrival times. The app then provides you with the possible options, journey times and prices for your journey.

You decide to select the fastest route and your required arrival time. The app confirms the quote and provides you with a guaranteed journey time.

The P4P app may offer you various incentives to switch your travel mode or alter departure time, in order to reduce the demand on a congested route. You may also be given the option to pick-up other travellers sharing the journey cost as well as the options to purchase travel add-on products, such as parking at the destination. If enabled the app may also "push" offers and adverts for destinations that you may pass on route. For example, it may offer you a discount for your journey if you start at a particular petrol station.

You decline the options offered and have a trouble free journey arriving at your destination on time, payment is then automatically deducted from your account and a receipt emailed/texted to you. However, if you have been delayed and arrive 15 - 30 minutes late, then no charge is levied because of poor time performance. If you arrive over 30 minutes late, you receive compensation equal to the original quoted charge.


I need to go check on my elderly mum in her town centre care home
I need to get there by 6.30pm and carry some stuff with me so I will drive, despite the traffic
Available Options
BY CAR
£2.30 | 17 min
BY TRANSIT
£1.50 | 25 min
BY CYCLE
FREE | 22 min
Your Trip A to B
BY CAR
The recommended route is 8km and will take 17 minutes.
CHARGES
£0.02 for maintenance
£0.18 for environment
£2.10 for congestion
total cost: £2.30
if you are delayed over 30mins you will be compensated £2.30


Your Trip Options
ADD ONS
YES
NO
Do you want to car share and save?
Are you willing to depart later?
Do you want to book parking at your destination?
Do you need insurance for this trip?
Rate Your Trip
Journey experience
How satisfied are you with the P4P service
YOU ARRIVED ON TIME
so you pay the quoted price of:
£2.30
A receipt for this journey has been emailed to you

If for any reason you decide to divert from your pre-agreed route or stop for some reason, you can either re-book or just drive on as normal, but in the latter case you will not be eligible for the guaranteed journey time and related benefits.

All vehicles will need to have a "black box" installed to enable billing. Users will still have an option to simply get in and drive and not pre-book their journeys but they will not be eligible for compensation. Drivers will also still pay from their account. Users with no access to the mobile phone app can call the P4P call centre and book their trip.

Details on the technology behind P4P and how our solution can work both now and in the future are presented in Chapter 4.

3.2.1 Adopting a new system

Once the scheme receives Parliamentary Approval, motorists will have around 18 months to prepare for its introduction. They will receive an explanatory booklet setting out how the new scheme will work. A large scale marketing campaign will begin to raise awareness of how P4P works and its benefits including assurances on the abolition of fuel and vehicle excise duties, existing tolls, HGV road user levy and emission charges.

At the next MOT[9] they will have the "black box" installed on their vehicle and sign up with the service provider. New vehicles will be required to have "black boxes" installed on first sale and foreign registered vehicles will require one to be fitted at the port of entry along and to provide a credit or debit card against which they will be billed. The service provider will be responsible for all billing arrangements and providing journey planning services.

Once motorists have had their black box installed in their vehicle they will begin to receive 'dummy' bill statements. Depending on the nature of the journeys made, these dummy statements will suggest alternative routes, times or modes which can be cheaper or faster. These nudges may alter people's journey patterns even before charging actually starts. Motorists will also be able to download an app to a smartphone, tablet or computer that at this stage will provide information on journey times, modes of travel and prices. The app will provide predicted journey times and compare that with actual times achieved and, where appropriate, highlight when the motorist would have received compensation for an excess journey time.

The early implementation of a 'dummy' pricing system will help motorists get used to P4P. It will also help to collect data and analyse pricing strategies to work out the technicalities before going live. Bus provision will increase during this transitional period so that users who make early adjustments have travel alternatives. Owners of older, more polluting vehicles will be offered a scrappage allowance to allow them to switch to cleaner vehicles and hence minimise future environmental charges.

Six months after Parliamentary Approval, annual VED will be charged at a rate that reflects the fact that it will be abolished when the scheme goes live. This will be a legal requirement set out in the Act.

About a year after Parliamentary Approval there will be a steady increase in the provision of buses in urban areas where the charges are likely to be highest. This occurred when the London Congestion Charge was introduced, to provide an alternative means of travel. Bus users and operators will be significant beneficiaries of the P4P scheme, with faster and more reliable journeys reducing operating costs and increasing demand and revenues.

[9]The MOT is an annual test of vehicle safety, roadworthiness aspects and exhaust emissions required in Great Britain for most vehicles over three years old used on any way defined as a road in the Road Traffic Act 1988.

Approximately 18 months after Parliamentary Approval and 24 hours before the scheme goes live excise duty on all road fuels will be reduced to zero. At the same time the London Congestion Charge, any low emission charges and all road tolls will also be abolished. Again this will be a legal requirement of the Act. The following day, the scheme will go live.

3.2.2 The pricing components of P4P

Making it clear to motorists what they are paying for will improve public acceptability and help general understanding of how travel decisions affect prices.

Maintenance and operating charge

This will be the only element that all motorists will automatically pay. The cost will vary slightly by type of road and highway authority based on the actual cost of maintaining the road network. There will also be variation in charges between cars, LGVs, HGVs and bus/coaches. Heavier vehicles will pay higher rates proportional to the damage (wear and tear) they cause to road assets. Transparency of these costs and regulation (discussed below) will lead to these costs falling in real terms, especially as initially they will be set at a level to enable highway authorities to clear the existing backlog of road maintenance.

Environmental charge

Whether motorists have to pay this charge will depend on how clean and quiet their vehicle is. This cost will also vary by location, being highest in areas with poor air quality and where traffic is intrusive such as in historic centres and near schools and hospitals. Less polluting vehicles will pay less. Again, we expect this element of the charge to diminish over time as vehicles become cleaner and quieter both with advances in technology and the change in behaviour that the charge will lead to.

Congestion charge

For the majority of trips, congestion is rarely an issue. The main issues occur in the morning and evening peaks in urban areas and on many of our key strategic links. Here congestion can be chronic leading to lengthened and unreliable journey times.

Where congestion does occur - that is, there is a noticeable reduction in speed from the free flow average - then a congestion charge will be levied. This charge will be set at a level to either achieve free flow speeds or, where traffic volumes are too great, to achieve a target journey time (how this will work is covered in section 3.3.2). Hence the charge will vary by time of day and section of road.

Motorists will have two options when travelling in a congested part of the network. They can either just get in their car as now and drive and pay the appropriate charge. Or book their journey, via their app, on-line or via a call centre. In exchange for pre-booking, they will be offered a discount and a guaranteed maximum trip time. If this trip time is exceeded by 15 to 30 minutes then the motorist will pay nothing for the journey. If it is exceeded by more than 30 minutes, the motorist is entitled to compensation equal to the charge they were originally quoted. In quoting a journey time, the app will take into account breaks in journey and the user's preferred driving style which it will learn during the run-up to the scheme's introduction, i.e. whether they drive at 60 or 70mph on a motorway, do they stop every hour or two hours for a break, etc.)

In the run-up to the introduction of the scheme, a considerable amount of data will have been collated on journey times by link, time of day, day of week etc which will allow reasonable forecasts of journeys times to be predicted. When the scheme is introduced guaranteed journey times will be based on this data but will continually be reviewed and revised as driver behaviour changes as a result of the scheme.

3.2.3 Driving behavioural change

Under the proposed system both the make-up of costs and the total amount paid by drivers will change. The transition from VED (a fixed cost) and fuel tax (an average cost), to marginal costs is important because marginal charging has a much bigger impact upon behaviour, in economic terms it has a higher price elasticity. The essence of this proposal is to shift driver costs from fixed and average costs to marginal cost. That change will mean that the marginal costs will be more transparent to drivers and will have a greater impact on behaviour.

In the current pricing situation drivers are faced with negligible marginal costs (4% of total user cost). Some 96% of their costs are fixed or average. The allocation of costs to categories is neither clear nor transparent. Fuel costs for example might be thought to be fixed on short trips (no impact at all on behaviour) they might be considered as average costs for trips of less than 20km when there is little chance of having to fill up with petrol, but on long trips of a hundred kilometres or more then we will expect fuel costs to be better taken into account – maybe as marginal costs.

A benefit of the marginal costing system will be that journeys along different road types will incur different costs. This will mean maintenance and mitigation revenue will be time and place specific. As a policy instrument to affect behaviour, P4P enables a precise approach that increases efficiency of achieving a specific outcome, such as reducing congestion.

3.2.4 Sample user profiles

We have selected a diverse sample of road users where each one drives a certain number of kilometres and uses a particular type of car depending upon their lifestyle or profession. Our scenarios also include the financial cost of their journey (fuel cost etc) and the time cost. Time is converted into monetary terms using values of time from the Department for Transport (DfT).

In generalised cost terms, taking account of both time and money, all users in the examples shown are better off. Those users who drive in congested areas at peak times (e.g. commuters) may experience cost increases but these will be offset by reduced journey times. LGV and HGV operators may experience higher financial costs but the time and hence associated costs savings will more than compensate. Those travelling on business (with higher values of time and hence major beneficiaries of faster journeys) and those who drive in rural and other uncongested areas will see considerable benefits.

It should be stressed that the prices used in the examples and this paper are based on a number of assumptions about how costs should be allocated between different user types. In reality, if P4P is introduced the regulator can set the charging framework in a variety of ways depending on the government's policy objectives. This is one of the major advantages of P4P; it has huge flexibility which enables behaviour and revenue to be constantly adjusted to fit what is considered best for the road network.

The figures for each of the example individuals are also based on the assumption that they will not change their behaviour. Part of the P4P approach is all about changing behaviour through better price signals. By making prices much more transparent, P4P will encourage mode shift, re-timing of trips, changes in destination, and use of more efficient and less polluting vehicles. These dynamic responses are not included in the case studies which therefore represent a "worst" case scenario.

WHO WE ARE

I work from home and mostly use our family car for the school run

I live in a small town and work at a nearby office

I am a regional sales rep and I spend a lot of time in my car

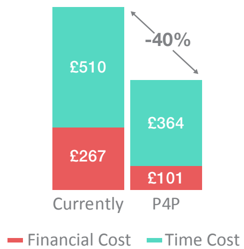
HOW WE DRIVE*

I drive 2000km in a comfy SUV, mainly for the school run

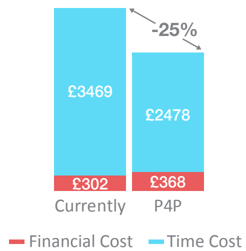
I drive 5000km for my short commute in my smart car

I use my car every day for work and drive 25,000km in my BMW

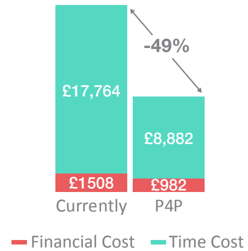
COST COMPARISON*



My journeys are now quicker and cheaper - no more traffic jams and with less traffic around school I am tempted to start cycling again with the kids



An extra £1 a week is well worth it as the drive to work is less stressful with far less delays and smoother journeys

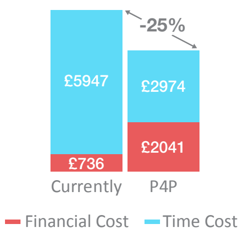


The boss cant believe it, I'm far more productive, I know exactly when I'm going to get to my appointments, driving in free flowing traffic is far less stressful and its costing the firm less

* annual figures

I live in the countryside but work in a nearby town

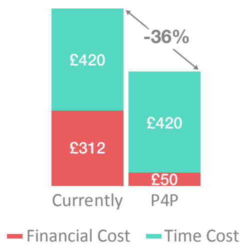
I drive 12,000km for my commute in my economical car



I pay far more than I used to but I now know exactly what time I'm going to get home and my commute takes far less time so I have more time to spend with the kids, which is priceless

I am a pensioner living in a rural area and drive occasionally

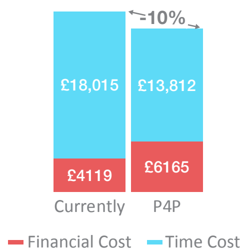
I drive 3000km in my old, small car, mostly for going shopping



All the potholes have gone on our local roads and its costing me less to drive than before

I am a full time professional HGV driver

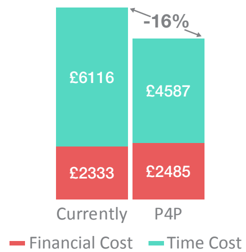
I drive long distances all over the country, covering 54,000km



The traffic jams, stop start traffic, lack of truck stops, long distance truck driving was a terrible job. Now its transformed with guaranteed journey times, far fewer delays and the boss is saving money

I am a Transit driver, delivering packages across Manchester

I drive medium distances each day mostly in urban areas and cover 21,000km



Less traffic jams means I can do far more drops a day so I earn more than the extra charges I have to pay. I'm going to get an electric van soon so I pay no environment charges.

3.2.5 The end result for drivers

How motorists use the road network is expected to change as soon as they start receiving dummy bills and will change significantly in congested areas when the charge is actually implemented. There will be a marked reduction in congestion and even at busy times, journey time reliability will radically improve. There are also likely to be fewer freight vehicles on congested parts of the network at peak times as they now have a financial incentive to re-time journeys to less expensive times of the day.

In the medium to longer term, as the various incentives take effect and money is allocated to where there is the most traffic and hence the most need for funding, motorists will experience better maintained roads, the removal of pinch points and the infilling of strategic gaps on the network. Journey times will be faster and far more reliable on the strategic road network and when things go wrong, the right incentives are in place for highway authorities to fix the problem and for users to receive compensation.

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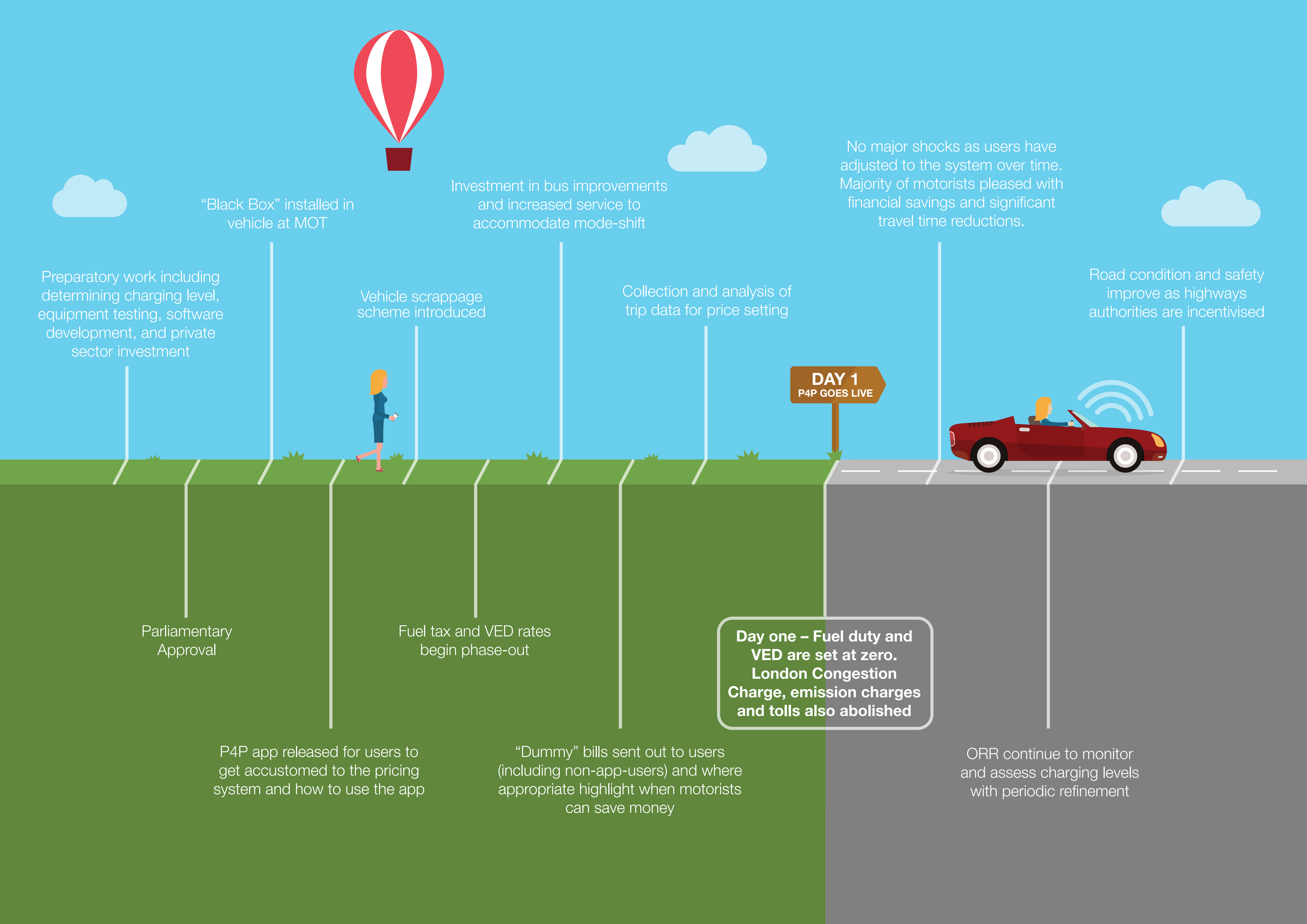
3.3 How P4P will be implemented

3.3.1 Government's limited role

The government's role will principally be to set the legal and regulatory framework by which the scheme operates. It will not be involved at all in its day to day operation. It will set the maximum congestion cost that can be charged so motorists know they will not be subject to price surges. To reduce the complexity of the scheme we recommend a reduction in the number of transport/highway authorities in the country although this is not essential for our scheme to work. In England for example, this could be reduced to Highways England responsible for the motorway network; the areas covered by regional mayors (e.g. Greater London, Greater Manchester, West of England, etc); and county councils covering the rest of the country. Each geographic authority will be responsible for all roads in its area except for the motorway network and will ideally also be responsible for all other local transport modes e.g. buses, light rail/trams and local rail services, thereby delivering holistic local transport services.

The government will also set up a transitional fund to operate until the scheme becomes live. This fund will be used to pay for a vehicle scrappage scheme (removing older polluting vehicles) and enhancement to urban bus networks.

The economic impacts of the scheme and its financial implications for government are set out in chapter 7.


Preparatory work including determining charging level, equipment testing, software development, and private sector investment
Parliamentary Approval
"Black Box" installed in vehicle at MOT
P4P app released for users to get accustomed to the pricing system and how to use the app
Vehicle scrappage scheme introduced
Fuel tax and VED rates begin phase-out
Investment in bus improvements and increased service to accommodate mode-shift
"Dummy" bills sent out to users (including non-app-users) and where appropriate highlight when motorists can save money
Collection and analysis of trip data for price setting
DAY 1
P4P GOES LIVE
Day one – Fuel duty and VED are set at zero. London Congestion Charge, emission charges and tolls also abolished
No major shocks as users have adjusted to the system over time. Majority of motorists pleased with financial savings and significant travel time reductions.
ORR continue to monitor and assess charging levels with periodic refinement
Road condition and safety improve as highways authorities are incentivised

3.3.2 An independent regulator sets prices

The Office of Rail and Road (ORR) is the independent safety and economic regulator for Britain's railways. It is also responsible for monitoring Highways England's performance and efficiency. Our scheme will extend the functions of the ORR so that it will be responsible for setting each of the three road charging elements and for monitoring the efficiency of all highway authorities.

Prior to the passing of the requisite legislation, the ORR will be tasked with setting the prices that will apply when the scheme is launched. These prices will then be reviewed on at least an annual basis and may be adjusted more quickly if required. Once the scheme has settled in it is envisaged the congestion charge will move to a completely dynamic system subject to maximum caps.

The congestion charge will be set using:

- standard speed/flow curves - for each type of road there is a relationship between the amount of traffic that can be accommodated and its speed; and
- price elasticities which will be refined by road type, location etc.

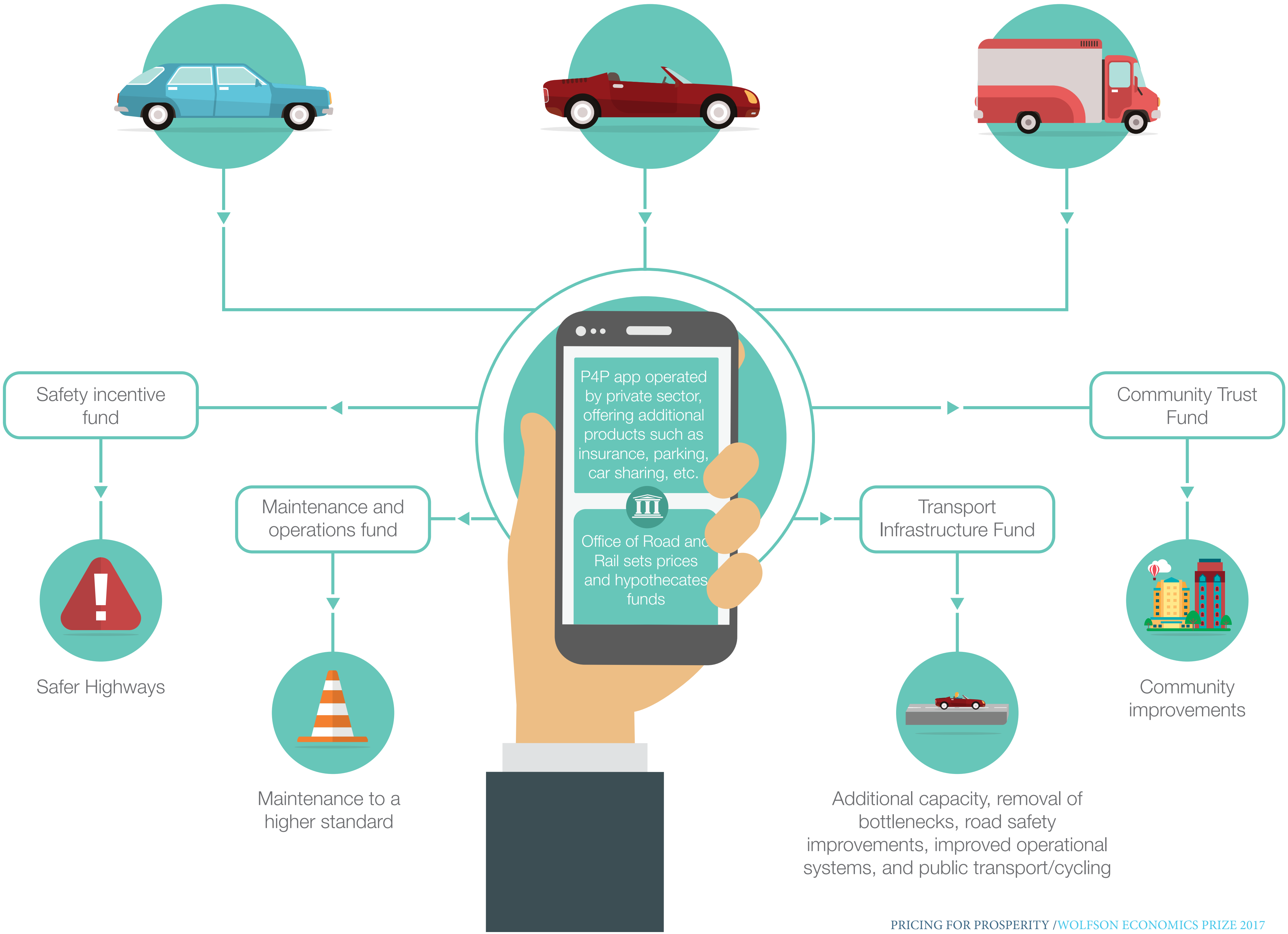
These parameters will be set by the Government in terms of maximum charges by road type/location to achieve free flow conditions or target journey times for each link.

The ORR will set the level of maintenance charge. This will be calculated by vehicle and road type to achieve an average charge across a highway authority's portfolio of roads. For example, all rural unclassified roads in the highway authority's area will carry the same maintenance charge per vehicle type. The charge will be set at a level that enables the highway authority to restore the condition of its road network to an agreed national standard within 10 years. The average backlog on road maintenance is estimated at 13 years in England10. The ORR will be responsible for improving efficiency in road maintenance and it is envisaged that annual increases in the road maintenance charge will be set at RPI-x so it decreases per vehicle over time. It is envisaged that the maintenance charge will also cover minor improvements to the network such as safety enhancements, junction improvements etc.

The environmental charge will also be set by the ORR based on the emissions and noise outputs of vehicles by road type and location. Initially, it is envisaged that the charge will be relatively crude; just a few location emission and noise charge bands will apply, based on existing air quality management areas and in the vicinity of schools and hospitals. They will then be refined over time to a separate charge per link on the road network to reflect local circumstances. Based on both national legislation and the change in behaviour the charge will facilitate, it is envisaged that the environmental charge will diminish over time as vehicles become cleaner and quieter. The monies from the environmental charge will go to a Community Trust Fund which will invite bids from communities and their local authorities that suffer from the negative externalities of the road network. These communities will be initially identified on the basis of proximity to roads carrying above a set volume of traffic but over time, as detailed air quality and noise monitoring is implemented, further fine-tuning can be developed.

The regulator will be responsible for ensuring revenues from the scheme are spent appropriately. In the case of congestion cost revenues these may only be spent on transport infrastructure projects. These may include the provision of additional capacity, removal of bottlenecks, road safety improvements, improved operational systems, and public transport/cycling provision (where this can be shown to reduce congestion in the highway authority's area e.g. in dense urban areas where it is not practical to provide new road capacity). An element of the congestion fund may be top-sliced by the government to set up a fund that highway authorities may bid for to carry out similar works in cases where their own funds are insufficient. For example, while a highway authority may have minimal congestion now and hence obtain minimal funds, new planned development could lead to considerable future congestion which investment now may prevent. In this instance, the highway authority could bid for funds for the scheme. In addition, this top slice will be used to set up a safety incentive fund, as explained below. Private sector operators will, subject to normal planning rules, be able to bring forward proposals for new roads with their own charging regimes.

10http://www.asphaltuk.org/wp-content/uploads/ALARM-2017.pdf


P4P app operated by private sector, offering additional products such as insurance, parking, car sharing, etc.
Office of Road and Rail sets prices and hypothecates funds
Safety incentive fund
Safer Highways
Maintenance and operations fund
Maintenance to a higher standard
Transport Infrastructure Fund
Additional capacity, removal of bottlenecks, road safety improvements, improved operational systems, and public transport/cycling
Community Trust Fund
Community improvements

3.4 Private service providers' interaction with users

While the proposals are passing through Parliament, the private sector will be invited to enter the market of providing the appropriate apps and billing services to motorists. Existing insurance companies could be the first businesses to enter the market. The motor insurance industry is spearheading the adoption of in-vehicle telematics similar to the black box we propose.

We envisage that the private sector providers will cover the cost of installation of black boxes as they will benefit from early information on motorists' journey patterns and can develop and provide additional products and services.

Within three months of the legislation passing, large amounts of anonymised information will be released to all private sector providers of journeys made by vehicles fitted with black boxes. This will allow further refinement of journey routeing and timing apps and for feedback from users.

Once the system goes live private sector operators will be competing on the basis of additional added value services and the lowest administrative costs as well as customer service.

3.5 Incentivising highway authorities

There are currently over 150 highway authorities in the UK and they face significant difficulties, including:

- Funding is erratic. Money is often allocated close to the end of the financial year and then has to be spent quickly on the 'use it or lose it' basis. That cannot be an effective way of delivering value for money;
- Spending on transport infrastructure tends to be "lumpy" and spread over a number of years which is not fit well with annual funding or bidding rounds; and
- Highway performance (speed, safety, reliability) has no impact on revenues. Whether you are operating the most efficient authority or the worst has no link to the amount of funding allocated.
- The overall P4P approach provides an opportunity to let the highway authorities work more efficiently. It does that by providing better incentives for efficient behaviour:
- Funding is no longer erratic and it does not have to be returned to the government if it is not spent. Highway authorities will be able to borrow on the basis of future revenue streams in order to resolve infrastructure issues sooner. Alternatively, they could bank revenue and wait until they have enough funding to proceed.
- Roads that are unreliable will cost highway authorities money as they will have to pay compensation to vehicles that have been delayed.
- Considerable delays are caused to road users by road works and accidents. Delays caused by these may be subject to compensation if users' journeys are seriously delayed. Routine road works and accidents will be excluded when determining journey times so highway authorities will be incentivised to minimise their impact and to improve safety on their networks.

In theory, there is no reason why a private company could not become a highway authority, probably through a fixed term concession/franchise. That might result in private sector investment in new road infrastructure and innovation and cost reductions in highway maintenance and building.

Safety incentive fund

The ORR will publish for each highway authority its three-year average safety record in terms of Killed and Seriously Injured (KSI). Using this as a benchmark the fund will pay annually the highway authority for reductions in the number of KSI to incentivise investment in safety improvements. If the number of KSI increases above the benchmark then the highway authority will be fined an equal amount.

4. How do we deal with technological change?

4.1 Transition to Connected and Autonomous Vehicles

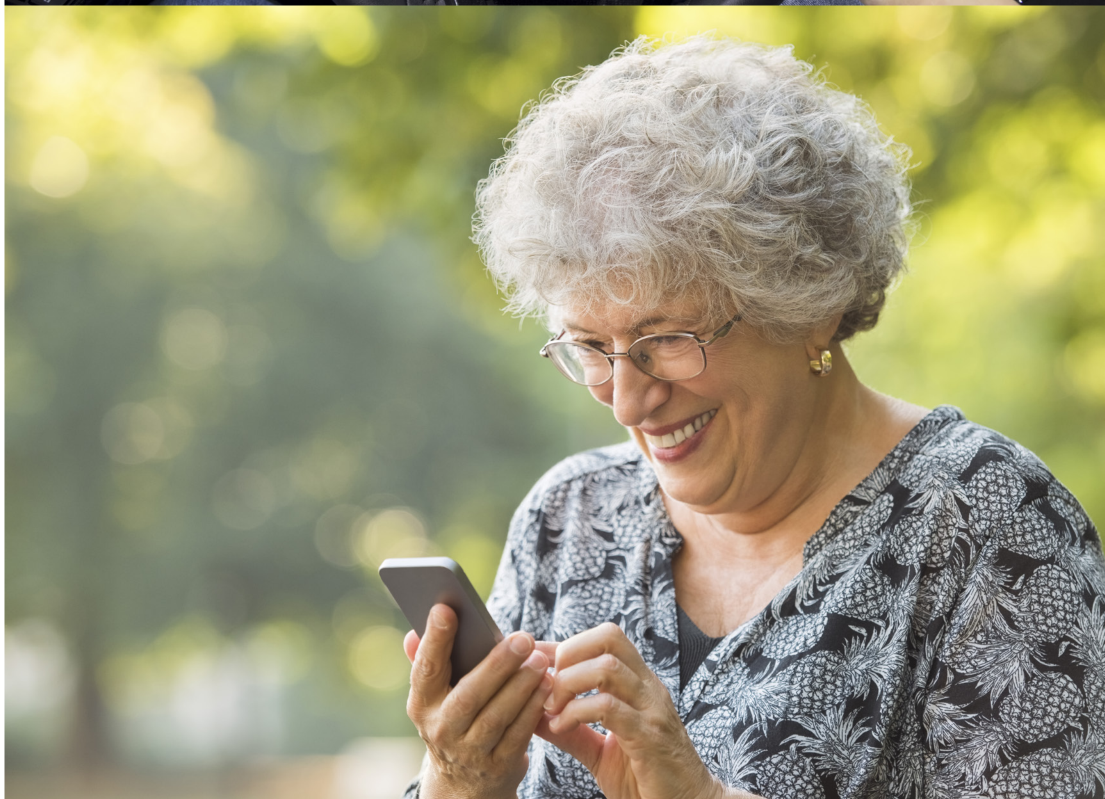
Connected and Autonomous Vehicles[11] (CAVs) and associated transport technology are advancing fast and in the near future will impact on how roads are used, the costs associated with driving and land use. This makes it even more important to have a solution that can adapt to technological and/or environmental change.

P4P can be implemented with and without CAVs, but the technology associated with CAVs (e.g. communication between vehicles) has the power to unlock the full potential of road pricing. We believe that CAVs and road pricing are complementary to each other. The system can work during the transition to CAVs, where there will be manual and automated cars sharing the roads, but also work in conjunction with initiatives such as Mobility as a Service.

A proactive approach is required to anticipate the effects of this technology and implement policies that will maximise its benefits and mitigate any potential harms. The following are impacts which we consider realistic and directly relevant to this study, but are not exhaustive:

- CAVs could radically increase highway capacity without building new infrastructure, such that capital investment in the network is not required or that congestion charging revenues fall to zero over a great proportion of the network.

[11]Connected & Autonomous Vehicles, driverless cars, automated cars, intelligent drive systems, robocars, self-driving cars, unmanned vehicles; there are many names currently being used both publicly and within the industry. It is unlikely an of cial name for the technology will be decided before the fully autonomous vehicle is launched. Consequently, for the purpose of this study, we will refer to vehicles using self-driving technology as Connected & Autonomous Vehicles (CAVs) unless otherwise stated



- CAVs will be safer than human drivers; over 90% of all accidents are attributable to human error. Reducing the number and severity of accidents will reduce compensation payments and the congestion caused by accidents.
- By removing the need to have an (in)attentive human behind the wheel, we will experience new types of trips that we cannot predict or even imagine today, for example, a CAV picking up your dry-cleaning, driving itself to the carwash or shared CAVs 're-positioning' themselves in anticipation for a surge in demand around a particular location. In addition, a large number of people who presently are unable to drive due to age or disability will be able to travel independently. Thus it is reasonable to expect a large increase in the demand for travel, as people will be prepared to make longer trips in greater comfort, especially if they can use that time to do something productive rather than driving.
- Without road pricing, CAV could therefore lead to a large increase in mileage, especially empty mileage. If it became cheaper to get your car to drive around the block a few times rather than having to pay for parking, then congestion could rapidly spiral out of control.

History has shown that increases in road capacity are met by increases in demand, while higher speeds are usually offset by driving greater distances. Left unchecked, sprawling urban areas expand ever outwards as seen in the US and Australia. Examples of potential adverse effects from CAVs' proliferation include congestion returning to previous levels as people travel more and further, public transport abstraction, air and noise pollution, declining physical activity and loss of agricultural land to greenfield development.

Our dynamic road pricing solution and CAVs equipped with cleaner propulsion systems, are highly complementary and can combat some of the negative aspects of CAVs. For example, CAVs have the potential to replace low frequency buses and trains (mostly rural and evening or weekend services) with much more efficient and attractive alternatives, including on-demand transport.

4.2 The technology behind our solution

Currently over 81% of the total UK population and over 90% of under 34 year-olds owns a smartphone12, with growth in ownership highest amongst older people. P4P can be implemented today, rolled out using ubiquitous mobile phone technology and an automotive black box with telematics capability which can receive and transmit information about the vehicle itself and its location. Installation of the black box is required to monitor journeys in lieu of using the phone app and for accurate billing.

At the scheme's launch, all vehicles will need to have the device installed either during the yearly MOT, manufacture or entry into the UK. Telematics for cars are becoming commonplace and cost less than £100. The black box will be a standardised device, reliable, able to operate in all weather conditions, crash and tamper-proof.

Table 2 describes the various stages we envisage that our solution will go through. The proposed stages will run concurrently since all vehicle types will be road charging-enabled by having the black box installed, regardless of how old a vehicle might be. Our solution also gives drivers the option to simply get in their cars and drive away, or enter their destination in the phone app and pay a lower price.

At the launch of P4P, we expect that many drivers will choose not to use the app, but this will diminish as drivers are nudged towards it. Drivers who do not make their route known will be retrospectively charged a higher price, based on the route they used. A bill for each journey will still be emailed to each driver accompanied by a comparison of the same trip when using the app. Drivers will not be eligible for compensation in the event of delays if they haven't logged their journey through the app.

In the short term, we expect technologically savvy users or early adopters to use the phone app to book and pay for a trip in advance. As the public directly experiences the benefits and incentives of using the app, this will become the dominant method of paying for road use in the medium term. In the long run, as vehicles become increasingly more connected and eventually fully autonomous, we expect that the large majority of people will be using the in-car app to pay for their road use.

This is the right time to introduce the P4P scheme before CAVs are introduced, given that it is hard to predict how quickly and disruptive transition to CAVs will be for tax revenues and road use. Now is the time to implement a road pricing system that is flexible and adaptable and can be used to support future infrastructure programmes, but also for people to get used to road pricing before CAVs become commonplace.

With P4P, manual and automated cars can co-exist by sharing the same road space in the network and paying seamlessly no matter what vehicle type or age. Our solution can accommodate technological advances – it can be both analogue and digital, for automated or human-driven cars, rural or urban areas, motorways or 20mph streets. Our system is flexible, adaptable and the pricing structure can be refined instantly.

Improvements in vehicle connectivity will make the management and implementation of the pricing scheme cheaper and easier, with all new cars having some form of telematics or connectivity features, such as the eCall13 emergency dialling service which has to be installed by law in each vehicle produced in the EU from 2018.

[12]https://www.deloitte.co.uk/mobileuk/

Table 2: Technological stages of P4P

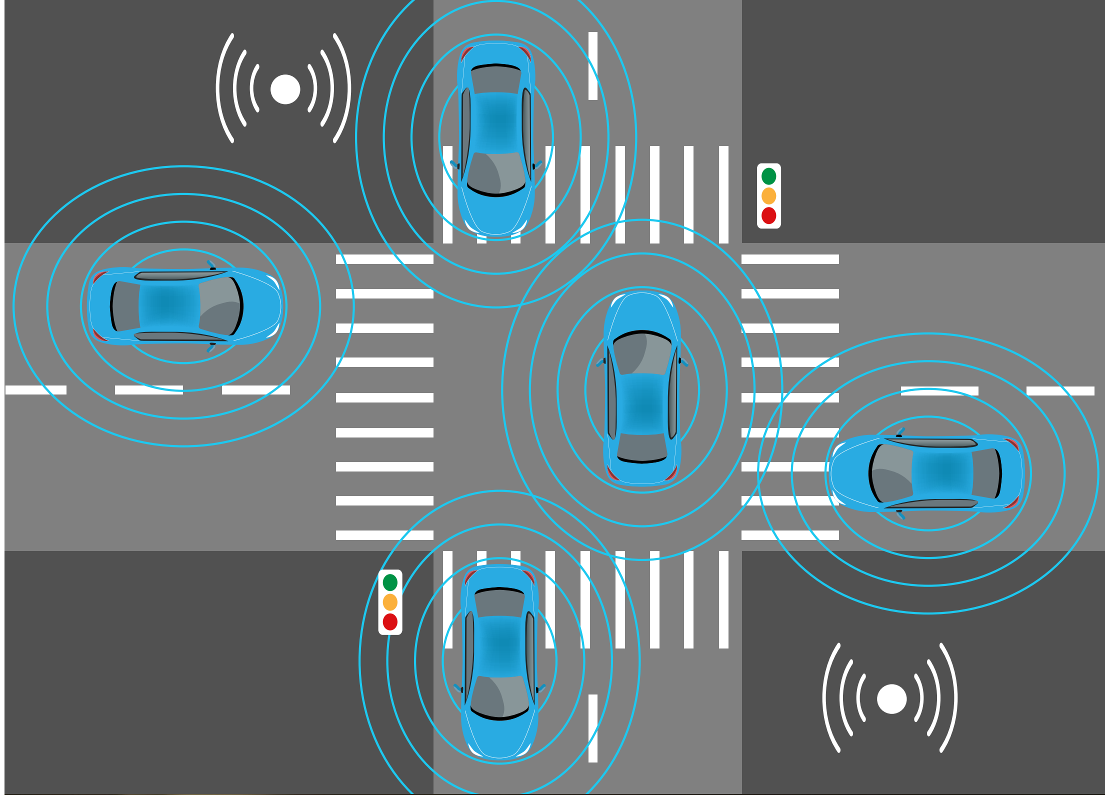
Stage	On-board technology available	Payment via	Road pricing in practice	Timeline
Stage 1: Manual car with basic connectivity	Automotive black box with telematics capability	1. Mobile phone app 2. Call centre	Early adopters will use the phone app to book and pay for a trip. We expect that this will become the dominant method of paying for road use. • Lower price paid compared with getting in the car and driving without entering trip details in the system. • Drivers will be eligible for compensation in the event of delays. • Updates in real time to help avoid congestion hot spots.	Short term (available now)
		1. Those who simply get in their cars and drive will be billed automatically 2. Call centre	This option will be for: • Drivers who just get in the car and drive; or • When mobile phone is unavailable (low battery, no signal) or not present; or • Drivers who cannot use a smartphone have the option to contact the call centre or drive and pay at the normal rates. • As no destination/route is known before embarking on a trip, the driver is charged a higher price based on the route they used and will not be eligible for compensation in the event of delays.	Short term (available now)
Stage 2: Early connected cars	Connected vehicles with 4G connectivity enabled and/or Apple CarPlay or Android Auto installed	1. Road charging app accessed via car operating system (similar to Tesla's central console touch-screen currently on sale) 2. Mobile phone app (as backup) 3. Call centre	• As the car fleet is renewed and there are more connected cars on the roads, the majority of people will use this option during this time period. • Drivers will be eligible for compensation in the event of delays. • Optimal road charging.	Medium term (2020 – 2030)
Stage 3: Fully connected and autonomous vehicles – mostly as a shared fleet, some privately owned	Multiple sensors and tracking devices installed, with a range of functions (e.g. pothole detection) and data logging devices (e.g. tailpipe emissions & noise levels recording).	1. Road charging app to run on on-board, factory installed devices 2. Standardised user interface (especially on shared fleet) 3. Handheld device (the 'mobile phone' of the future) as backup	• Optimised road charging • Efficient traffic network management and operation • More effective road asset management • Drivers will be eligible for compensation in the event of delays • Optimised grid energy use • Rise of new and disruptive business models in related sectors • Potential to offer discounted or free trips if occupants of CAV agree via a smart micro-contract (blockchain) to 'consume' targeted advertisements by companies such as Google or Uber etc.	Long term (2030-40)

A driver can have a classic, manual car made future-proof by having a telematics device retrofitted at its next MOT, ensuring that the car has at least some level of connectivity. The driver then will be able to book a trip via a range of options: phone app, call centre or just get in and drive. This car can be operated long into the future, even if driven by a human on a CAV dominated road space.

The proposed black box design can be specified to include a basic level of connectivity between cars and/or infrastructure so that vehicles are able to exchange basic operating instructions. For example, a non-automated car equipped with a black box waiting at a junction to turn against oncoming traffic will send a request to nearby fully automated cars to inform them that they want to turn. This has the potential to alleviate many technical and safety concerns during the period of mixed fleet operation since all cars will have at least some basic level of connectivity.

There are multiple benefits based on this solution. Real-time data from all vehicles and a good understanding of how people respond to pricing, based on data analysis and experiments, will result in moves towards network refinement and optimisation. Machine learning, and later on Artificial Intelligence14, can potentially be utilised to manage the system and monitor users' behaviour in order to keep traffic flowing at optimum speeds, all the time.

In combination, all of these new technologies will provide an opportunity to inexpensively charge road users, and enhance traffic management across the network.



[13]From March 2018 every new car sold in the European Union will legally have to be equipped with eCall technology.

This will consist of equipment that detects a crash and automatically calls the emergency services for help via the pre-installed SIM card. Vehicles will also be fitted with a GPS sensor so it can send the car's precise location to the control room in case of an accident. Data will be collected periodically not constantly.

4.3 Virtual Personal Mobility Assistant

Our solution is inclusive and accessible for all. For drivers without access to a mobile device (no battery, phone not present or owned) or unable to use the phone or in-car app, they can still just get in and drive, but will pay a higher charge and forego eligibility for compensation in case of delays.

The app can be imagined as a virtual personal mobility assistant, similar to how Google Assistant or Amazon's Alexa have both become intelligent personal assistants to users. Most devices with intelligent personal assistance allow users to activate the app using a wake-word (such as 'OK Car') or by requiring the user to push a button to activate the listening mode on the phone or car.

4.4 CAVs and improved asset management

As CAV technology is perfected and deployed, driverless vehicles will face another hurdle: the built environment. Current roads, intersections and signage were built to accommodate human drivers, pedestrians, and cyclists. Infrastructure will need to adapt to make it safe for all road users.

Improving road infrastructure to better accommodate CAV technologies poses significant costs, which is challenging for relevant authorities already struggling to upkeep infrastructure. At the same time, increased CAV deployment may reduce revenue streams from parking and fines that help pay for maintenance or fund other road-related expenses.

CAVs will create a new set of maintenance issues for highway authorities which will require funding. For example, current research in CAVs has shown that some technological solutions which enable the car to visualise the road space and 'perceive' the surrounding environment have issues navigating around standing water. A predictable driving environment with well-marked traffic lanes and other road markings are necessary for current CAV technology, so highway authorities will need to improve lane striping and signage. Thus, substandard roadside drainage, road markings but also road obstructions such as vegetation and debris, become of primary importance in the discussion on the future of road asset management. Therefore, funding this new type of road asset management will become critical as CAVs become commonplace on our roads.

It is likely that in the near future CAVs will be able to collect information on the condition of the road (e.g. pothole locations, surface condition) and upload it to a centralised database in real time. This can be achieved by using a combination of vibration data collected by on-board sensors and GPS data to determine where potholes or other defects are and plan to repair them in a timely manner. In turn, the database can inform routeing decisions for other cars, highlight dangers along a route and plan accordingly in real time. The Londonworks15 database, operated and maintained by Transport for London, is a database where every roadwork location and duration is recorded; this can be considered as a predecessor of future more comprehensive asset management systems.

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[14]Artificial Intelligence and Machine Learning, which include technologies such as deep learning, neural networks and natural-language processing, can also encompass more advanced systems that understand, learn, predict, adapt and potentially operate autonomously. Systems can learn and change future behaviour, leading to the creation of more intelligent devices and programs.

[15]http://public.londonworks.gov.uk/ 15http://public.londonworks.gov.uk/

As CAVs will be able to keep an accurate central position in the road space (e.g. driving between road markings, if any) while travelling at speed, this might lead to more frequent rutting of the road surface. Today, this is a maintenance issue experienced locally rather than along the whole road network – in the future, this might become a significant asset management issue which will potentially need a rethink on how we design, build and maintain our roads.

Having accurate, up-to-date information about the condition of the road surface and the location of dangers on the road or roadworks will all be prerequisites to the safe and efficient operation of CAVs. The road condition data collected by CAVs will not only aid in navigation and routeing but also make asset management more efficient - and our solution can pay for such high-quality road maintenance and associated databases to support the network.

4.5 Road pricing and insurance

The motor insurance industry is spearheading the way for the adoption of in-vehicle telematics similar to the black box we propose. The uptake of such devices and sharing of driving habits with the car insurer is encouraged by lower insurance premiums, especially for younger drivers. Car insurers in many countries have already invested heavily in telematics which record various parameters regarding driving and the vehicle itself, which are then transmitted to a platform where the data are analysed in an effort to offer more accurate insurance quotes. This means that by offering an automotive black box, the insurance industry has already created a link in the public mind between road usage, driving behaviour and price.

4.6 Road pricing enabled CAVs – a new urban management tool

CAVs are likely to lead to a significant increase in the number and distance of trips. Our proposed pricing approach will leverage the benefits of CAV technology to ensure that the UK road network improves, rather than just maintains the status quo or leads to more congested and environmentally degraded conditions. Depending on the road pricing philosophy chosen, traffic volumes, car parking and car ownership patterns can be managed through pricing.

The price set under P4P for using or accessing a CAV will have a direct impact on how cities experience their benefits (or disbenefits), as shown in Table 3.

Table 3: Charging for CAVs

Impact on	Low-price scenario	High-price scenario
Traffic volumes	Significant increase in demand (vehicle kilometres travelled), offset by increase in capacity of road network in the short term. In the long term demand likely to exceed capacity	Price used to curb the increase in demand and as an incentive to change travel behaviour (e.g. time of travel)
Public transport	CAVs may replace low demand bus and rail services and act as feeders to high capacity public transport corridors and rail stations	
Car ownership patterns	Variety of car ownership models: outright ownership, on-demand hire (from a private or public operator), car sharing	Fewer people own a CAV outright, most hire on-demand
Urban structure	People may be more inclined to travel longer distances. Geographical decoupling of home/ work location, resulting in urban sprawl and higher energy consumption	Concentration of homes/ workplaces leading to urban containment which may also constrain energy consumption

5. How can we make road pricing acceptable to the public?

5.1 Introduction

Paying to drive is not a popular policy. In 2007 1.8 million people signed a petition against the then government's road user charging proposals. In 2005, 75% of voters rejected Edinburgh's road user charging scheme and in 2008, 70% of Manchester residents voted against a similar scheme. However, since London's congestion charge was introduced in 2003, there has been little opposition to it despite the daily congestion charge rising considerably.

There is no point developing a system which cannot be implemented because it is unacceptable to the public. It doesn't matter how good the technical solution is if it cannot win the popular argument as well as the technical one. So how can 'pay as you drive' be made acceptable to drivers, the opinion formers in the tabloid press and hence ensure politicians view road pricing if not necessarily a vote winner then at least not a vote loser?

There are a number of issues surrounding public acceptability including privacy, trust and equity. These are dealt with in turn below.

5.2 Issues affecting public acceptability of road pricing

Perception of trust

While the previously rejected national road pricing schemes planned to introduce pay-as-you-go road pricing to replace existing fuel duties and VED, few motorists believed that they would not end up paying more in tax than they did. The city-specific schemes were viewed as additional payments with no perceived benefits to road users.

The new legislation will need to explicitly set out that fuel and vehicle excise duties, along with existing congestion charges, tolls, HGV road user levy and emission zone charges will be abolished as soon as the new scheme is introduced. The law will need to ensure that prices will be set by an independent regulator and not the government and that a clear aim of the scheme is to introduce guaranteed standards of service and to drive efficiencies in road maintenance.

The private sector will operate the billing system with companies competing to offer a range of complementary services in a similar way to airline and railway ticket selling websites. For example, offering insurance and breakdown cover, offering discounts at catering/retail outlets that may be along or slightly off-route, or a reduced charge by breaking a journey at times of peak congestion.

Mitigate impacts on low-income groups

Older more polluting vehicles tend to be operated by lower-income drivers who under the scheme will end up paying more to drive the same routes as those in more modern vehicles. Before the scheme goes live, a vehicle scrappage scheme will be introduced aimed at enabling individuals to replace older, more polluting vehicles with newer, more environmentally friendly vehicles. Initially, the aim will be to replace those vehicles that do not meet Euro 3 petrol and Euro 4 diesel emission standards.

Blue badge holders

The charging apps will be able to offer a wide range of services to those with disabilities and it is proposed that blue badge holders will be entitled to a discount on the congestion charge in line with the discount offered by the disabled person's railcard.

Hypothecation

At present around a third of the revenue raised through road taxes is spent on the road network. It is envisaged that our scheme will result in 100% hypothecation to transport as a whole, as present support to the rail sector of some £4bn a year can easily be covered.

To begin with revenues can fund the backlog of road maintenance on local roads which is estimated at £12bn, the vehicle scrappage scheme, covering the cost of bus subsidies, including concessionary bus passes and enabling an extension in the provision of bus services, bringing forward a considerable number of road enhancement schemes, such as bypasses and road widenings, increase in traffic policing, and enhancements of the road network. This may include a network of urban tunnels (which though expensive, under a road charging scheme may be justifiable) to remove traffic in areas of high pollution and to invest in 5G connectivity in anticipation of CAV deployment.

P4P can also cover the cost of new rail-based public transport schemes such as rail and trams where there are benefits to road users by supporting mode shift from congested road networks. The establishment of the Community Trust Fund will also benefit communities negatively impacted by the road network enabling them to mitigate or offset those impacts as outlined in section 3.3.

This is not an exhaustive list and will include funding mitigation against unforeseen impacts.

Traffic displacement

The road network offers a vast range of alternative routes between any two locations. The advent of satellite navigation devices has seen vehicle flows increasing on routes that may not be designed for them or that previously were relatively quiet.

The scheme addresses this issue in two ways. The first is through the environmental element of the scheme. Sensitive roads can be priced accordingly, reducing their attractiveness for rat-running. Secondly, the Community Trust Fund will enable those impacts to be significantly reduced.

Incentive schemes

At the outset, the scheme will operate on normal vehicles with driver control. The black box will monitor driver behaviour and offer suggestions on how to improve their driving. Cars equipped with black boxes, which always stay within the speed limit and those that are well driven (smooth manoeuvring, braking, accelerating) could be entered into a weekly prize draw or rewarded with points. This gamification of driving might encourage younger drivers to embrace P4P and provide an extra nudge to drive better, safer and in a more environmentally sustainable manner.

Pay not to drive

The highway authority can potentially encourage people not to make regular trips at congested times, if it reduces the likelihood of having to pay users compensation. For example, if 1,000 people commute every day from A to B at 8am causing fluctuating levels of congestion, offering a random 10% of them every day with a discounted bus/train ticket or paying them to travel earlier/later could reduce severe congestion and the cost of compensation to everyone.

5.3 Privacy and the potential of blockchain technology

Concerns relating to privacy of user data are a major barrier to road pricing implementation.

An integral part of P4P is the use of blockchain technology which has the potential to radically enhance privacy while ensuring secure transfer of data. We believe that by utilising the opportunities that blockchain technology can offer, road pricing and, at a later stage, self-driving technology, will become more palatable to the public. Blockchain technology is rapidly evolving, and it makes it possible for people to pay for their road use in a different way (including sharing or hiring a CAV), whilst at the same time safeguarding privacy and providing a secure method of payment.

Similar to the internet, blockchain is an open, global infrastructure upon which other technologies, platforms and applications can be built. In fact, blockchain technology might form the backbone of what is sometimes referred to as a 'new type of internet'. In simple terms, blockchain[16] is a type of a ledger or decentralised database that keeps records of digital transactions. Blockchain allows routine business transactions to be frictionless, performed in real-time without requiring a trusted third party. Every transaction, for example, transfer of funds from one account to another, is recorded in a secure and verifiable form by using mathematical techniques borrowed from cryptography.

[16]Blockchain refers to a virtual, secure chain of data blocks which store records of all transactions, so that a list (ledger) of all user account balances can be generated. These data blocks are long strings of characters that are unreadable by humans – and this type of data encryption is what enables anonymity. According to the requirements of a particular application, a ledger can be made public (decentralised) or private (centralised).

> "The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value."

Don & Alex Tapscott, authors of Blockchain Revolution (2016)

Blockchain technology allows two parties to record simple, enforceable contracts without a lawyer and makes it possible to sell almost any kind of property or right without a broker. These are sometimes referred to as 'smart contracts' under which people can choose to remain anonymous while enabling third parties to verify that they shook, digitally, on an agreement. By allowing people, businesses or governments to bypass traditional intermediaries in their dealings with each other, transaction costs are lowered or even eliminated – especially for commercial applications which require frequent micropayments such as road pricing.

The potential of blockchain is evident in the increasing investment in the sector, with billions already invested into start-ups formed to exploit blockchain for a broad range of businesses and applications. Technology giants such as Microsoft, Google, IBM and also the big accounting firms and many banks all have blockchain projects underway. Many of these companies are attracted by the potential to use blockchain to reduce fraud and increase trust with greater security.

Governments around the world (including in the UK, the Department of Works and Pensions) have been investigating the technology as it has the potential to help deliver public services more effectively, for example:

- collect taxes;
- deliver benefits;
- issue passports;
- manage the land registry;
- ensure the security of a government asset and prove that it hasn't been tampered with;
- assuring the integrity of government records and services;
- minimise fraudulent activity; and
- improve inconsistent data quality.

The most digitally advanced government in the world is Estonia and it has been claimed that by signing 'anything and everything digitally via blockchain'[17], the efficiency gain of the whole economy is worth at least 2% of the country's GDP.

Bearing in mind the rapidly evolving technological landscape of blockchain, four ways where we envision blockchain technology to contribute towards the acceptability of road pricing, especially when complemented by (shared) CAVs are privacy protection, managing and monetising personal data, frictionless billing, and accounts auditability and transparency.

5.3.1 Privacy protection

With blockchain, users can choose their preferred level of personal anonymity as they don't necessarily need to state or include personal details for a transaction to take place or store those details in a central database. This is important to note as it eliminates the need for centralised databases to store personalised data, with the risk of hacking. The blockchain protocols allow users to choose the level of privacy they are comfortable with according to the type of transaction or application.

[17]http://www.taaviroivas.ee/koned/2017/2/13/london-fintech-conference-february-8-2017-opening-speech-1

Blockchain has the potential to prevent road pricing-enabled cars and later CAVs from harvesting personal data. The blockchain-enabled identity of each driver or passenger (in a shared vehicle) will include basic relevant details such as driving licence number, age, insurance and payment details while giving the option to protect personal identity and journey information. Most vehicles, especially connected vehicles, will also need to have a blockchain-enabled identity, storing all relevant details about the particular vehicle and payment methods.

Note that under our scheme, all users' anonymised journey data will be used to manage the road network regarding congestion and road maintenance.

5.3.2 Managing and monetising personal data

Today, people all over the world use social media, apps or other services for free in exchange for their personal data. The personal data we create in our everyday lives have value, yet the users who create these data do not have control over them. Blockchain offers users an opportunity to control the personal data that 'connected' activity generates and potentially monetise it. For example, trip related data transactions can potentially be sold to any interested parties (traffic data collection companies) or shared with retailers in order to receive personalised product promotions.

One application which attempts to monetise personal data is the Enigma[18] project under development at Massachusetts Institute of Technology (MIT), where user privacy is viewed as the key precondition for creating a personal data marketplace. Enigma is a privacy-preserving platform (data remains encrypted even in-use) which allows the sharing of data with third parties to analyse. For example, it is possible to run sophisticated forecasting models for energy or transport, without actually giving the data away.

[18]http://www.enigma.co/ http://livinglab.mit.edu/wp-content/uploads/2016/01/enigma_full.pdf

The Enigma platform is built from a network of computers that can store private data and process it, without being able to see the data they are operating on, by combining Secure Multi-party Computation with blockchain technology.

5.3.3 Frictionless billing

It will be easier for a driver or passengers in shared CAVs to pay for their journeys and for the relevant highway authority to collect their share of road pricing revenue. Smart contracts on the blockchain will automatically connect shared CAVs to passengers and provide a secure way of paying not only for individual trips but also for other motoring costs such as fuel, electricity for charging, parking etc. All such transaction costs will be lower since no third party will be required to process the payment.

5.3.4 Accounts auditability and transparency

Auditing road pricing accounts and revenue hypothecation will be streamlined since blockchain enables each trip's details to be registered in a standardised template ensuring accurate, instant collection of revenue and reporting of accounts. In principle, blockchain can also enhance public scrutiny by being able to track where and how the hypothecated revenue is spent, for example, if it is in accordance with the road regulator's spending commitments. Combined with the non-tampering capability of blockchain, this will increase the public's trust of the scheme .

5.4 Blockchain application for vehicles

Blockchain is already being used in related areas. Products and services based on blockchain technology are well suited to play a vital role in helping cities, highway authorities, app developers and entrepreneurs to come up with innovative transport solutions. Swiss bank UBS has teamed up with automotive technology company ZF and German energy company Innogy SE to build blockchain-based eWallets[19] for future electric cars allowing car owners to pay for electric charging, parking fees, tolls and receive car sharing fees.

The Toyota Research Institute[20] has recently launched a consortium of companies, including MIT Media Lab, to explore different aspects of blockchain technology which may be applied to the car industry and how software, in general, will help people become comfortable with autonomous technologies. Initially the research will focus on collecting and sharing data on road use; on developing tools to make ride-sharing easier; and to create usage-based insurance products.

In summary, blockchain applications in combination with on-demand ride-sharing services and CAVs have the potential to dramatically change the face of urban transport, by creating a variety of new and previously unimagined solutions.

5.5 Why is our solution better than other schemes?

Public

The public will get the road network it deserves. Quicker, more reliable, lots of options available by varying the time of day and route but fast, reliable and direct when you need it and are prepared to pay for it. In addition, for the communities that are negatively affected by road noise and pollution there will be a significant investment to mitigate those effects.

Government

The central government stands to lose most of its revenues from the highway sector over the next two decades. Our proposed approach delivers a better road network, requiring less investment because of price demand management, whilst covering not just its direct operation, maintenance and capital investment costs but also environmental impacts.

[19]http://www.ibtimes.co.uk/ubs-collaborates-blockchain-wallets-cars-1599055

[20]http://www.reuters.com/article/toyota-selfdriving-blockchain-idUSL1N1IO178

Wider connectivity improvements

This is not a narrow road-focused system. It is designed to promote walking, cycling and public transport use as well as producing a more efficient road network. At the trip booking stage alternative modes will be presented on a comparable basis enabling well-informed decisions. A positive effect will be a boost to public transport, both from the switch of demand from car to public transport and from the faster journey times delivered by the reduction in congestion. Also, people making short trips will have a clearer financial incentive to walk or cycle.

Future technology

Our solution is designed to operate with the technology available today, but can easily be refined to take into account future technology such as CAVs and thus avoid becoming obsolete. The technology behind our solution offers freedom of choice for drivers, whether to get in and drive or input their destination in the app before departure and enjoy the benefits. Importantly, blockchain can alleviate concerns surrounding privacy and data security in a 'Big Brother' society.

6 Environmental and social impacts

6.1 Environment

A 2012 Europe-wide study[21] estimated that the external cost of road transport in the UK was £48bn a year, covering pollution, noise and accidents. The environmental element of P4P is designed to address the global and local environmental externalities of driving. The core purpose of the environmental charge is to act as a lever to alter and continue to influence behaviours – of vehicle users, vehicle manufacturers and highway authorities. The purpose of the environmental 'pot' is to finance the mitigation schemes that alleviate the adverse effects of environmental externalities on people and the environment.

The environmental externalities that will be targeted are greenhouse gas (GHG) emissions, noise generation and air quality emissions (NOx and particulate matter). In addition, an account can be taken of the intrusive nature of road transport on sensitive areas, e.g. historic centres, hospitals, schools etc. As with every aspect of P4P, these categories can be reviewed and changed periodically as the cost of externalities change, new ones arise, or further behaviour changes are sought.

The pricing of these externalities is congruent with current policy initiatives but seems likely to achieve results more efficiently. Introducing the environmental charge as proposed will help the UK meet its climate change goals, improve local air quality, and increase the liveability of communities by reducing noise and loss of life due to accidents.

[21] Prof. Becker (2012), The True Costs of Automobility: External Costs of Cars Overview on existing estimates in EU-27, Techische Universitat Dresden 2012

6.2 Combating climate change

The UK Climate Change Act 2008 made significant commitments to reduce GHG emissions in the UK. Currently, GHG emissions from vehicles are priced in the form of fuel duties of around £0.58/l on petrol, diesel, bioethanol and biodiesel. The fuel price has averaged at between £1.15 and £1.20/l in May 2017. The GHG element of this is therefore significant. The proposed system will provide marked improvement over the current charging scheme, by driving behavioural change and recognising the cost of externalities by charging emissions-based prices. These will be lower than current fuel duties and correspond more accurately to the emissions of each individual vehicle. The charge will be collected through the payment system, rather than at the pump.

Diesel vehicles, which emit less CO2 than petrol ones (the reason for the previous reduced level of fuel duty and resulting popularity) will, therefore, pay a lower GHG component within the pricing mechanism than petrol vehicles. Other alternative fuel vehicles will also be charged lower rates for lower emissions. We expect P4P to result in lower GHG emissions due to fewer miles being driven by high emission vehicles including a switch to electric vehicles. Overall the system is fairer and rewards users that have cleaner vehicles.

6.3 A national 'Clean Air Zone'

A report from the Royal College of Physicians and Royal College of Paediatrics and Healthcare estimates that air pollution causes around 40,000 premature deaths in the UK each year[22]. MPs have declared air pollution a public health emergency. During May 2017 DEFRA released for consultation the government's Draft UK Air Quality Plan for tackling nitrogen dioxide. This plan stops short of suggesting major taxation changes or a diesel scrappage scheme. What it proposes is to create several Clean Air Zones around the UK, additional funding for alternative fuels and electric taxis, further research into HGV road user levies and new emissions testing to reflect real-world emissions better. P4P will create incentives to achieve the same goals as proposed in the DEFRA plan, through a single initiative.

P4P will improve air quality by addressing congestion. Air pollutants are worsened by stop-start traffic, albeit the extent to which reducing congestion will reduce pollutant levels is unclear. A study by researchers from Imperial College London using portable emissions measurement systems found that on average vehicular NOx emissions were 20% higher under 'urban driving'. By reducing traffic levels in congested areas, the congestion component of P4P will deliver positive health externalities as NOx levels with free flow traffic are reduced. Our high-level estimate of the impact of reduced congestion on air quality, places the health and environmental value of reduced pollution at approximately £300m to £1.2bn per annum.

[22]Royal College of Physicians (2016), Every breath we take: The lifelong impact of air pollution. Report of a working party. London: RCP, 2016.

Environmental charges will act as another lever to reduce harmful vehicle emissions. The environmental component paid by users under P4P will function much like a 'Clean Air Zone', however, it will operate everywhere. The vehicle and location-based environmental charge allows for the collection of a charge that depends on the vehicle's air pollutant emission rate, the local air pollutant concentrations, and the number of people nearby that are impacted. It will be a variable charge like the congestion charge. However, this does not mean that users will pay more under this scheme than under the Clean Air Zone case; rather it means that everyone will contribute to cleaner air, while being less likely to penalise users in certain locations. With all users contributing (as opposed to proposed Clean Air Zone initiatives), drivers of diesel and older vehicles will not feel that they are being singled out – an additional point for public acceptability. Further savings to the government will also result because this approach will avoid the need for expensive monitoring and collection infrastructure.

Link-based charging also provides flexibility with regards to reducing air pollutant emissions. Some routes will be costlier than others. All else being equal, driving through a city centre will be more expensive than taking a bypass, because air pollutants tend to be highly localised, so the impact is greater in a city centre than outside due to population densities. Sometimes pollutant concentrations vary on a link-by-link basis on roads and therefore drivers will be given options for route selection and informed of the price difference between the options. The flexible pricing option will push polluting vehicles to the routes where their impact will be less, and does so in a way that a Clean Air Zone cordon cannot.

Particularly sensitive areas such as schools and hospitals can be prioritised so that the price of NOx emissions near them will be higher than average, due to the long-term health implications of effects on children. It is recognised that initially public objection to higher 'school zone' pricing may be a concern for parents wishing to drive their children to school, however, this mechanism will eventually drive adapted behaviour such as carpooling or mode shift, and most importantly improvements in the health of our children.

We expect that air quality hotspots will be significantly reduced as a result of both vehicle and location based charging for pollutant emissions because these areas will have the highest air quality environmental charges.

6.4 Noise

Traffic noise causes a nuisance to residents and those working adjacent to busy roads thereby also reducing the amenity value of adjacent properties. It can also have adverse health effects in certain circumstances. A 2007 study of traffic noise in the EU (EU22) estimated the annual cost at €40 billion, based on annoyance and health costs, with the bulk (about 90%) of costs due to noise from passenger cars and lorries[23]. Currently, drivers do not pay for noise, which ignores the cost that vehicle noise imposes on others. The approach to noise charging under P4P will work similarly to charging for air pollutants and be based both on absolute noise emissions and where that noise is generated. Silent electric vehicles will therefore not pay any noise mitigation, and vehicles with noisy mufflers will be charged accordingly.

We expect that noise hotspots will be significantly reduced as a result of both vehicle and location based charging for noise emissions.

23Den Boer, L.C. and Schroten, A. (2007). Traffic noise reduction in Europe, CE Delft, 2007.

6.5 Safety

Our proposed safety incentive fund discussed in section 3.5 will give clear signals to highway authorities to improve the safety of their roads. One of the largest factors cited in favour of CAVs is the safety gains from eliminating driver error.

6.6 Fleet improvement

With drivers paying user charges that cover the true environmental and social cost of driving their vehicle, there will be an incentive to switch to vehicles with lower marginal costs - whether this means electric motors, smaller vehicles or other technologies that reduce the negative external impact of driving. Evidence from the implementation of London's Low Emission Zone (LEZ) suggests that the withdrawal rate of non-compliant vehicles increased by 10-20% around the year of the LEZ implementation[24].

An increase in demand for low-externality vehicles is expected to encourage vehicle manufacturers to invest in new technology and in research and development that promotes the creation of vehicles of the future. The increased demand and manufacturing capabilities will strengthen the UK's position in the global automotive market and the green economy.

6.7 Environmental Mitigation

Capturing the environmental costs imposed on others by vehicle users within our scheme will facilitate the development of a Community Trust Fund. This will be used to deliver tangible improvements that everyone can benefit from. These may target environmental externalities such as air quality or noise. Large, freestanding (i.e. not attached to vehicles) air filtration technologies and carbon sequestration techniques are not yet viable but could be in the near future. Noise barriers are a common mitigation practice. Alternatively, the Community Trust Fund will be flexible enough to allow local authorities to achieve alternative community-enhancing improvements. This may entail creating parks or playground spaces, investment in community or leisure centres, or to help meet other local needs. Communities and local authorities will have the flexibility to apply mitigation in the way that works best for their localities.

[24] Ellison et al., Five years of London's low emission zone: Effects on vehicle fleet composition and air quality, Transport Research Part D, 2013

7. Financial and economic appraisal

7.1 Financial appraisal

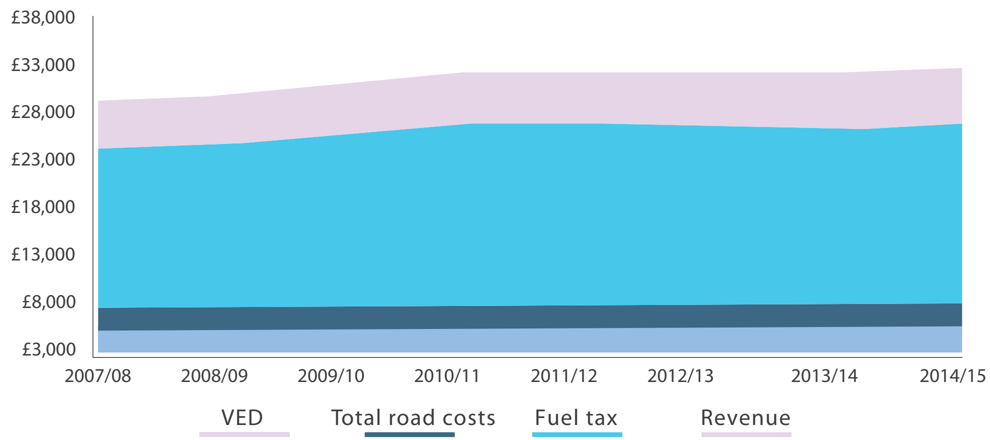
7.1.1 Introduction

This chapter provides an indicative analysis of the financial and economic implications of P4P. While it follows Department for Transport guidance, it is by its very nature based on a series of assumptions and simplifications. All revenue from P4P is assumed to be hypothecated to transport, and based on our assumptions, revenue from the scheme broadly matches total UK transport spending so there is little overall impact on government expenditure and revenues. However, until more detailed modelling is undertaken, the congestion charge elements of P4P can only be an educated estimate at this stage. We have also assumed considerable upfront spending in terms of the vehicle scrappage scheme. This spend can be scaled back if necessary by targeting owners in areas where the environmental charge is expected to be highest.

7.1.2 Current costs and revenues and how they will change

Figure 12 shows both revenues and direct costs of the road system for 2007/8 to 2014/15. At present road users generate a surplus for HM Treasury of approximately £25 billion as only £8 billion of the £33 billion in revenue is actually reinvested into the road system. Fuel duty makes up the vast majority, £27 billion, of the £33 billion revenue. Fuel duty revenues are, however, declining and expected to reduce substantially, possibly to zero by around 2050.

Figure 12: UK road revenue by type and road expenditure for 2007/08 to 2014/15



In terms of future revenues, Figure 13 displays future fuel duty and VED revenue alongside maintenance costs under three different do nothing scenarios – i.e. a future without the P4P scheme being implemented. Each scenario operates under a different assumption of changes to fuel duty revenue, with the annual change to VED revenue remaining at -2.1% (based on CEBR 2015 prediction of VED revenue[25]) for all scenarios. Table 4 gives a breakdown of each scenario.

Figure 13 shows that government revenue will decrease in real terms under all scenarios. The high forecast scenario is considered unlikely, as the rate of increase in fuel duty receipts is decreasing each year and vehicles are becoming more fuel efficient. The middle scenario is based on recent trends in fuel duty revenue; between 2004 and 2014 leading to a decrease in revenue in real terms – a trend that is assumed to continue. This forecast does not allow for any increase in fuel efficiency or switch to electric power. The low scenario assumes a steady 1% reduction in fuel usage. Governments could increase the fuel duty rate but they have become increasingly reluctant to do so in recent years, it has been frozen for eight years.

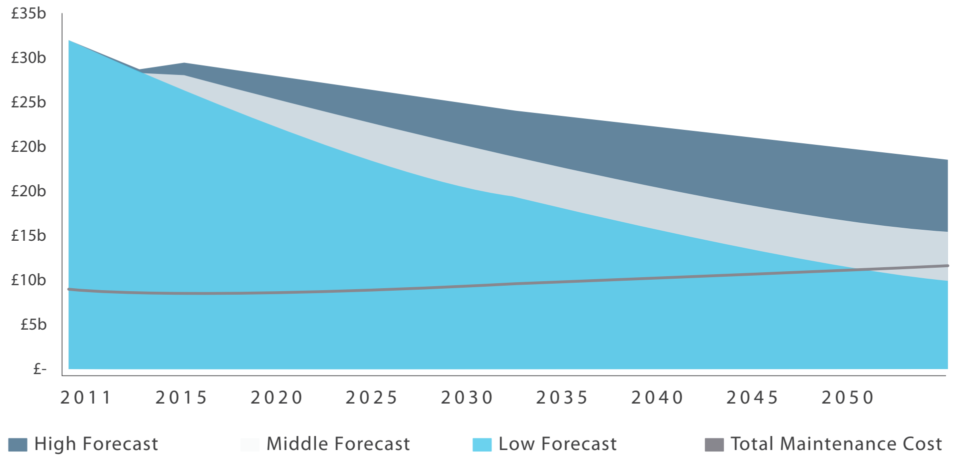
In order to examine the financial impact of P4P, we have made a set of assumptions about the appropriate level of charges and how that compares to current average vehicle usage costs, largely based on published data.

The figures presented below represent one scenario out of many possible ones. For this study, it is not possible to determine precise prices for every location and time of day. However, the beauty of a pricing solution is that it can be varied at almost no cost in the light of observed behaviour. There will be the flexibility to reduce or increase charges by type (congestion, environment, maintenance), by location (motorway, urban, rural), by time of day and between different user/vehicle categories as better information becomes available. At a simpler level, this type of charging system is in place for the UK's electricity and gas national grids.

Table 4: Fuel duty and VED revenue forecast scenarios (based on CEBR, 2015)

Forecast type	Fuel duty parameters	VED parameters
High forecast	Based on average growth per annum from 1990 to 2014 (4%)	VED -2.1%
Middle forecast	Based on average growth per annum from 2004-2014 (1.5%)	VED -2.1%
Low forecast	Based on reduction of 1% per annum as a result of significant change in fuel efficiency/consumption	VED -2.1%

Figure 13: Expected decline in government revenues from roads



[25]CEBR, 2015, The future of motoring taxation, A report for the Society of Motor Manufacturers & Traders (SMMT).

7.1.3 Maintenance charge assumptions

According to data from the DfT, road maintenance costs in 2015 were around £4.5bn. Allocating this between motorways, urban and rural roads and dividing by the total number of vehicle kilometres on each road type suggests an appropriate maintenance charge as shown in Table 5 below.

Over time, we envisage that the average maintenance charge will gradually decline as electric cars and CAVs are expected to be lighter and do less damage to the road. In addition, we expect the regulatory regime will also drive efficiencies. A decrease in the maintenance charge of 1% a year has been assumed.

7.1.4 Environmental charge assumptions

The environmental charge accounts for a number of externalities imposed by vehicle users on others:

- Noise – based on DEFRA estimates of the annual cost of noise from traffic;
- Emissions of greenhouse gases - WebTAG; and
- Local air quality - WebTAG.

Again, the charges per kilometre are envisaged to decline over time with the introduction of electric vehicles and/or CAVs. Table 6 shows the charge per kilometre in 2020, and how this might have changed by 2030.

Table 5: Maintenance charge (pence per kilometre)

Vehicle Type	Motorway	Rural	Urban
2020 (car)	0.09	0.18	0.24
2030 (car)	0.07	0.13	0.18
2020 (LGV)	0.27	0.54	0.73
2030 (LGV)	0.20	0.40	0.54
2020 (HGV)	0.81	1.62	2.20
2030 (HGV)	0.60	1.19	1.62

Table 6: Environmental charge (pence per kilometre)

Vehicle Type	Motorway	Rural	Urban
2020 (car)	1.72	1.45	1.56
2030 (car)	1.03	0.87	0.93
2020 (LGV)	6.36	4.33	6.02
2030 (LGV)	3.81	2.59	3.60
2020 (HGV)	7.94	8.38	11.81
2030 (HGV)	4.76	5.02	7.07

7.1.5 Congestion charge assumptions

Table 7 shows that 75% of vehicle kilometres will not be subject to any congestion charge, and for those that are charged it will be on average £0.03 pence per kilometre. At extremely high levels of congestion, the charge could be up to £0.80 per kilometre, but this is only the case for around 1% of vehicle kilometres – most trips, even journeys at peak times in city centres, will pay far less than that.

Changes to the congestion charge over time will be directly linked to changes in the number of vehicles over time and changes to capacity. For example, the introduction of CAVs will increase capacity since they can safely travel whilst close together and hence will reduce the congestion charge.

The congestion charge will be set at zero at low levels of congestion, increasing as the level of traffic relative to road capacity increases. For simplicity we have used five congestion bands (where congestion = volume / capacity) in line with the DfT's published figures:

- Less than 25%;
- Between 25% and 50%;
- Between 50% and 75%;
- Between 75% and 100%; and
- Greater than 100%.

For the first two categories, there will be no charge. With congestion above 50%, the assumed charge is in line with the external costs of congestion from WebTAG, with uplifts applied to reflect the level believed necessary to reduce congestion to an acceptable level.

Table 7: Congestion charge (pence per kilometre, 2020)

Congestion band	% of traffic	Average road (pence/km)
<25%	43%	0.0
25% - 50%	32%	0.0
50% - 75%	17%	0.7
75% - 100%	8%	28.0
>100%	1%	81.0
Weighted Average		3.2

Congestion costs are higher for certain road types/times of day, so although Table 7 shows the average congestion charges per kilometre, in practice there will be a range around these. Table 7 also indicates the proportion of traffic travelling at each congestion level in 2015. These charges have been used to estimate a weighted average congestion charge for each road type, shown at the bottom of Table 7.

7.1.6 Net financial position

The introduction of this new pricing system will naturally have significant implications for the government's net financial position. Two scenarios are described below, but P4P can deliver a wide range of outcomes depending on government priorities. It may be that environmental costs are actually much higher than we currently believe. In that case, the system could introduce higher environmental charges which will also impact on the choice of vehicles and mode.

Figure 14 shows the net financial position for the government under two scenarios:

- Do Nothing: road charging system remains as it is at present, with VED and fuel duty revenues declining over time due to the reasons outlined above;
- P4P system is introduced in 2020 and maintains government highway revenue at a more stable level over time.

2020 is recognised as an optimistic date by which P4P could be introduced and the further into the future it commences the less the financial impact on government.

For road users, the impacts will be as shown in Table 8. Taking into account

Figure 14: Government highway revenue (Do Nothing and P4P scenarios)

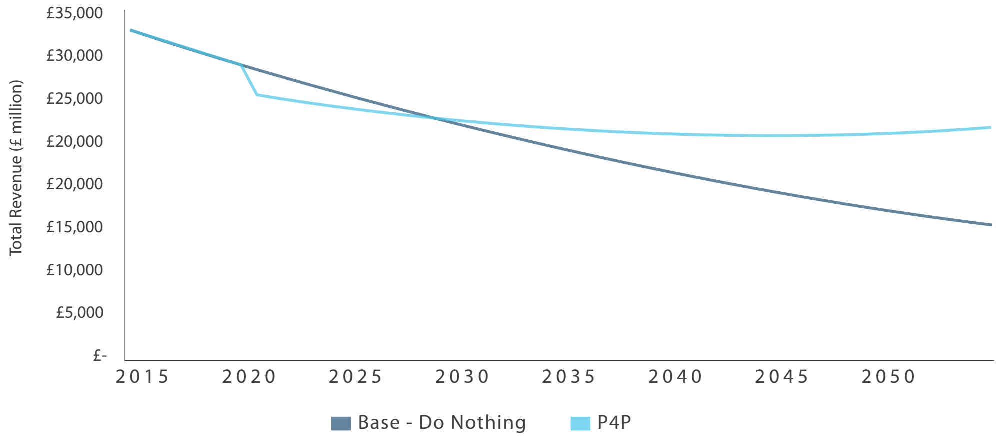


Table 8: Financial and time impact by vehicle type, 2020-50 (difference between Do Nothing and P4P scenarios, £bn)

	Car			LGV			HGV		
	Financial benefit	Time benefit	Total benefit	Financial benefit	Time benefit	Total benefit	Financial benefit	Time benefit	Total benefit
2020	6,600	4,000	10,600	-1,800	900	-1,000	-1,700	300	-1,400
2030	2,200	6,100	8,300	-1,700	1,400	-300	-1,300	500	-800
2040	-2,100	9,500	7,400	-1,800	2,200	400	-1,100	800	-400
2050	-6,300	14,900	8,600	-2,100	3,400	1,300	-1,100	1,200	100

Table 9: Benefits of different types of response to P4P

Response to P4P	Driver of change	Congestion	Environment	Safety	Highway maintenance costs
Change of route	Decide to take cheaper, slower route at peak times due to congestion charge	Material improvement	Material improvement: fewer emissions and improved local air quality due to less congestion	Unknown - depends on the characteristics of the existing and new routes	Neutral
Change of journey time	Decide to travel outside the peak due to trip not being time critical	Large improvement	Large improvement: fewer emissions and improved local air quality due to less congestion	Neutral	Neutral
Mode of transport	Reinvestment of funds collected from congestion charge leads to improved public transport	Large improvement	Large improvement: fewer emissions and improved local air quality due to fewer highway trips	Large improvement - fewer highway trips, therefore fewer accidents	Slight improvement
Increased vehicle occupancy/ shared trips	The technology used within P4P makes it easy to collect a passenger along the way/ advertise that you would like to share a journey and be collected	Slight improvement - or large if there is a significant increase in shared trips	Slight improvement - or large if there is a significant increase in shared trips	Slight improvement - or large if there is a significant increase in shared trips	Slight improvement - or large if there is a significant increase in shared trips
Decide not to travel	Decide not to make the trip as it is non-essential and prefer not to pay the marginal cost for that particular trip	Slight improvement - or large depending on how many trips make this change	Slight improvement - or large depending on how many trips make this change	Slight improvement - or large depending on how many trips make this change	Slight improvement - or large depending on how many trips make this change

the changes to time costs as well as financial costs, all vehicle types will be better off in the long run, with the vast majority benefiting immediately. These figures are indicative, and the government/regulator will be able to alter the balance of costs and benefits between vehicle types as desired. Financial costs can also be mitigated as the potential to switch to electric vehicles increases in the future.

7.2 Economic appraisal

P4P will not only make driving cheaper for most road users, it will also provide significant economic benefits to drivers and the UK overall. We have used the Department for Transport's 'WebTAG' economic appraisal guidance to place an indicative value on this.

The benefits that have been included are as follows:

7.2.1 Congestion relief

Congestion is a real problem in the UK. According to a report in February 2017[26], the direct cost of congestion to the UK – the time and fuel wasted and the impact on the environment - will average £10.6bn a year between 2013 and 2030.

Our system is specifically designed to make the best use of technology to price road use such that congestion is substantially reduced, relieving people of the misery of congestion and boosting the economy. Different trips will respond in a variety of ways to P4P, as outlined in Table 9, but all types of response will bring about benefits in some way, and every type of response will contribute towards reducing congestion.

To put a value on this benefit, we analysed the potential impact of our system on average speeds on different road types. The overall average figure for all vehicles is a 4% improvement to vehicle speed, but this includes journeys that are on uncongested routes. For journeys that are currently made on highly congested routes, the change will be much larger.

With faster journeys, less time will be spent travelling. A monetary value can be placed on this by using the DfT's data on the value of time. The value of time varies by journey purpose – business trips place a higher value on time (around £18 an hour) than commuter or leisure trips (£12 and £5.50 an hour respectively).

We estimate that P4P will lead to a reduction in congestion worth £5.2bn a year if implemented in 2020, rising to £8.0bn a year by 2030.

The appraisal does not include any benefits associated with the introduction of CAVs. CAVs will enable more capacity through cars running closer to one another, but could also worsen congestion through induced demand in a Do Nothing scenario with no road pricing system. It also does not include reliability benefits. Based on major road scheme appraisals we expect reliability benefits to be worth around a quarter of the congestion benefits, that is, well over £1bn a year.

7.2.2 Tax and road user charges

The impacts from the financial appraisal must also be taken into account in the economic appraisal. From the perspective of road users, there is a large benefit in terms of no longer having to pay VED and fuel duty, but the financial 'disbenefit' of paying the road user charges must be offset against this.

In the first year of the scheme, road users overall will benefit financially to the tune of £2.6bn. By 2030, this will become a net increase in payments of £1.1bn. This value

[26]CEBR (2017), The economic effect of road investment, https://www.fairfueluk.com/publications/files/assets/common/downloads/publication.pdf

is relative to a 'Do Nothing' scenario and reflects the fact that government highway revenues are expected to decline if no action is taken, whereas our system will keep users charges at a steady level.

7.2.3 Externalities

A reduction to total vehicle kilometres will lead to a reduction to some of the disbenefits that drivers impose on others, such as the number of road accidents and level of emissions.

In 2020 our scheme will see a decrease in externalities worth £1.3bn. By 2030 this will increase to £1.5bn a year.

7.2.4 Agglomeration

There is a positive relationship between density and productivity – with higher density comes more competition between firms, access to wider labour and product markets and increased knowledge spillovers, all of which boost average output per worker. Economists refer to this effect as 'agglomeration'.

Increasing accessibility leads to increased density because a faster journey time from A to B means that those two places are effectively closer together and therefore more able to enjoy the benefits of density.

Using our forecasts of journey time improvements and the DfT's guidance on agglomeration benefits, we estimate that our scheme will boost total UK Gross Value Added by £800m a year in 2020, increasing to £950m a year by 2030.

7.2.5 Expansion of output in imperfect markets

Markets typically operate in a state of imperfect competition. This means that firms keep output below its optimal level so as to maximise profit.

A reduction to transport costs incentivises firms to expand total output, generating a benefit to the economy. We have measured this using the DfT's appraisal guidance.

The 'imperfect competition' benefit of our scheme is £190m in 2020, increasing to £290m a year by 2030.

7.2.6 Initial costs

On the costs side, a number of impacts are also included within the economic appraisal. It is assumed that the following initial costs will be incurred:

- Cost of installing black boxes in all vehicles. As of the start of 2017, there were 37.3m vehicles licensed for use on roads in the UK. If it is assumed that the average cost per vehicle of installing a black box and any other associated costs of developing the system is £200, then taking into account further growth in vehicle numbers by scheme opening this suggests a start-up cost of £7.9bn;
- £1bn of marketing costs the year before P4P begins;
- £5bn a year in years -1, 0 and 1 of the scheme, to cover the costs of the vehicle scrappage scheme that forms part of P4P; and
- The cost of enhancing bus services so that the public transport offer is improved. This is assumed to cost £1bn the year before opening, reducing by £100m a year until reaching zero at year 10.

We recognise these costs are substantial but are deliberately conservative and in the case of the vehicle scrappage scheme and public transport enhancements are not essential for the principal of P4P to work.

7.2.7 Operating costs

There will be administration costs from running the scheme and collecting the revenues. This is assumed to cost 10% of revenues. The costs of collecting fuel duty at present must be netted against this. Evidence suggests that this cost is between 1% and 5% of collection – we have assumed it is 1%, i.e. current collection costs are at the lowest end of the scale and hence the net additional operating cost of P4P is at the highest end of the scale.

In addition, more vehicles will need to be set up with a black box over time. According to the DfT, the number of licensed vehicles is increasing by around 680,000 a year – so based on the assumptions outlined above, this will equate to an additional £136m of costs each year over time. We have conservatively included this cost throughout the duration of the appraisal, although in reality we expect it to reduce over time as vehicles become more and more connected and autonomous and hence do not require an additional black box to be installed.

As a result, the operating costs amount to £2.5bn in 2020, decreasing slightly to £2.3bn by 2030.

7.2.8 Revenue from tax and road user charges

This works the same as the financial charges to users, but in reverse. The loss of VED and fuel duty is a benefit to consumers but a cost to government, whilst the revenue from the new road use charges is a disbenefit to consumers but a reduction in cost to government (and is therefore entered as a negative cost in the economic appraisal).

In the first year of the scheme, there will be a net cost to the government of over £2.6bn. However, by 2030 the government will receive £1.1bn more in revenue than in a 'Do Nothing' scenario, with the figure increasing over time.

Table 10 shows a summary of the total benefits and costs of the scheme over the first 30 years. This is done in a manner consistent with the DfT's guidelines, using a discount rate to convert everything into a Present Value (PV).

This shows that the scheme will bring about almost £180bn of economic benefits as a PV over 30 years. As a comparison, Crossrail, Europe's largest infrastructure project, has a 60 year benefit of around £20bn.

The Benefit/Cost Ratio (BCR) of 5.6:1 is in excess of the BCR of 4:1 that the DfT considers to represent very high value for money – the scheme produces high economic benefits relative to its costs.

Table 10: Economic appraisal of proposed scheme

Economic Appraisal	£m, PV 30 years
Time savings	162,400
VED & fuel duty	372,700
Road use charges	-408,100
Highway externalities	28,000
Agglomeration	17,400
Imperfect competition	5,900
TOTAL BENEFITS	178,300
Initial costs	26,400
Operating costs	40,600
VED & fuel duty revenue	372,700
Road use charges revenue	-408,100
Total costs	31,600
Net Present Value	146,700
Benefit/Cost Ratio	5.6

Case Study: Impact on buses

P4P will have a positive impact on buses. Congestion is a major problem for bus services because:

- Congestion leads to slower and less reliable journeys, reducing demand. More people in the UK commute by bus than all other forms of public transport combined; it is a very important mode. People from lower income groups are more reliant on buses, and slower bus journeys reduce the size of their travel horizons for accessing jobs.
- Congestion increases operating costs and reduces revenues. As a rule of thumb, every 10% fall in operating speeds leads to an 8% increase in operating costs.
- Congestion is bad for the environment. Under heavily congested conditions, tailpipe emissions can increase by a factor of three or fourfold.

With P4P, the following groups will benefit:

- Bus users: journeys will be faster, particularly during peak periods in towns and cities. In 2015/16, people travelled 28 billion kilometres by bus in Great Britain, of which just over half were in cities. Even if P4P only improved bus speeds by 5% for a quarter of those trips, it would save passengers £40m of time a year.
- More people will also use buses – evidence suggests that for every 1% improvement in bus journey time, patronage increases by around 0.6%. So in the example given above, there would be a 3% increase in patronage, representing an additional 110m bus passenger kilometres a year.
- Bus operators by:

1. Increasing patronage: the average yield per bus passenger kilometre ranges between 20 and 25 pence, so in the example above an additional £25m a year of bus revenue will be generated.
2. Saving on operating costs: faster speeds lead to an improvement in efficiency. An improvement in speed for some journeys as outlined above equates to an operating cost saving of around £40m a year.
3. Reducing the peak vehicle requirement. In busy urban areas with high levels of congestion, more buses are needed to maintain a set frequency of service. So with P4P, it may be possible to satisfy bus demand with fewer vehicles travelling at a faster speed.

- Other road users: the greater mode shift to bus, the better it will be for people who continue to travel by car. More road space will be available since buses take up less highway capacity per passenger than cars.
- Public sector: if bus revenue increases and operating costs decrease, this suggests that a reduction to bus subsidies could be possible. Although, subsidies typically cover off-peak services whereas the improved revenue/operating costs will be brought about during the peak. In 2015/16, net support from local and central government for local bus services was £900m. So by improving buses' financial position by £65m a year (£25m extra revenue/£40m fewer costs), up to 7% could be saved on bus subsidies.
- Wider society: reduced congestion and faster bus speeds will mean fewer emissions and improved local air quality, benefiting a wider group than highway users themselves.

7.3 Summary

Our scheme will significantly reduce congestion across the UK, making journeys faster and more reliable. It will benefit the economy by boosting productivity and output on a much larger scale than other transport schemes. In the long run, it will also enable the government to raise more revenue for transport than under the current system of VED and fuel duty with their declining yields.

The scheme will have a positive impact on many different groups:

Commuters/labour market

P4P will provide better information to drivers and price road-use such that congestion decreases, with some users changing route, time, mode or not travelling at all (eg more working from home). This means that trips, particularly in urban areas at peak times, will become faster, saving people time.

This will also have a positive impact on the economy. Workers will be better connected with jobs and more people will choose to enter the workforce, boosting total output.

Businesses

The reduced congestion will also benefit business trips. In particular, P4P will:

- Enhance the ability for freight to undertake 'just-in-time' deliveries, reducing warehousing requirements and improving efficiency;
- Provide firms with better access to clients and customers, producing 'agglomeration' benefits to the economy; and
- Change land use, although the pattern that this will follow is unclear. Nonetheless, P4P will provide firms with more of an opportunity to be based where they really want to, without having to be as concerned about congestion or journey unreliability.

Government

With an increase to economic output, the government tax yield will increase. P4P offers an alternative to fuel excise duty which has a limited future.

8. Why we think P4P is the best solution to the Wolfson Economics Prize question

"How can we pay for better, safer, more reliable roads in a way that is fair to road users and good for the economy and the environment?"

P4P will fundamentally change how roads are paid for. It is a holistic solution for better UK roads, which ensures that:

- The road network is self-sustaining, covering all of its costs (direct and indirect) from user charges;
- The revenues flow directly from drivers to the appropriate authority and for the appropriate purpose; and
- It will enable funds to be spent on catching up on the backlog of road maintenance and providing new and improved transport infrastructure in a transparent and effective way.

Additional investment in roads alone will not ensure safety, which is why P4P incentivises highway authorities to reduce the rates of killed and seriously injured road users, through a safety incentive fund.

The congestion element of P4P will not only lead to less congestion and more reliable journey times but also by hypothecating funds to transport schemes will enable new transport capacity across all modes to be provided to address the UK's transport infrastructure deficit thereby providing not only reliable roads but a more reliable transport system generally.

A marginal pricing approach will send better signals to users about the external impacts of their road use. It will change an inefficient charging system with almost no link between price and user behaviour, into one which provides full information to road users on journey costs, journey time, alternative routes, and modes available. This will change behaviour, leading to better decisions and a better road network for both the economy and the environment.

P4P will be accompanied by a comprehensive marketing and communication strategy to explain the benefits of the approach to the public and to show how it promotes fairness and equity. In an effort to convincingly show that users will be better off, P4P will commit to deliver the following:

- Road journeys that represent a contract between highway authorities and users for a guaranteed level of service. Failure to meet guaranteed journey times will result in refunds or compensation;
- The scrapping of fuel and vehicle excise duties, congestion charges, HGV road user levy, emission charges and tolls;
- A road payment system that re-invests proceeds in the transport network so users experience improvements;
- The mitigation of environmental impacts to road users and non-users alike;
- A Community Trust Fund that prioritises vulnerable communities and those most affected by traffic noise and pollution;
- Complete anonymity to users if requested ;
- Promoting economic growth rather than inhibiting it through taxation, levies, or rationing; and
- Reducing transaction costs and administrative overhead by embracing technological advances.

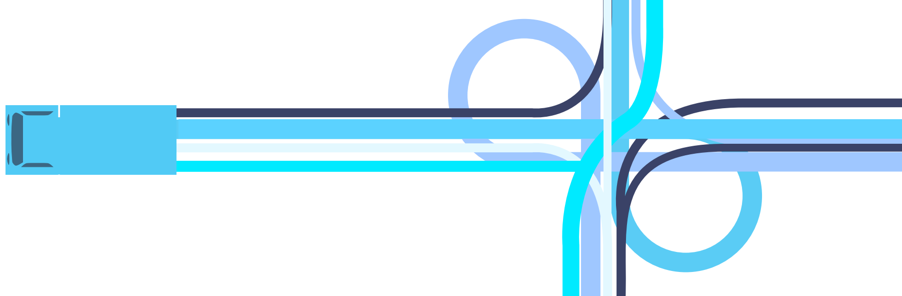
The wider economic impact of P4P is estimated to be worth £51billion over the first 30 years, in present value terms. It is also expected to have impacts on the automobile and technology sectors by creating new markets for mobility products. All while ensuring no overall change in the government's financial position.

Environmentally, P4P can enact policy goals on a national scale, with local specificity, which will be extremely effective for reducing emissions and noise and improving air quality. No alternative approach is as efficient and effective as pricing the external impacts in the way that P4P proposes.

The time to enact a comprehensive road pricing scheme is now. The case for a paradigm shift is evident, UK roads are not up to the standard that users want and expect. A consideration of other options shows that they suffer from drawbacks that P4P does not have or can ameliorate. The flexibility inherent in the P4P pricing, means that future disrupting technologies or unexpected and unwanted outcomes can also be addressed through this approach. An aversion to a dramatic change such as P4P is understandable, but with the current technology and other societal trends in transport usage, we expect the public to adapt and embrace it.

Choose Pricing, for Prosperity

Policy Option	Reduces Congestion	Optimises Network	Improves Environment	Covers Road Maintenance	Supports Electric and Autonomous Vehicles	Equitable	Economic Impact
Fuel Duty	✓	×	✓	✓	×	✓	-
Rationing car use	?	×	?	×	✓	✓	-
Road building	?	×	×	×	✓	×	+
Pricing/ restricting parking	✓	×	✓	✓	×	×	-
Targeted levies (e.g. HGVs)	×	×	✓	✓	×	×	-
Cordon pricing	✓	×	✓	✓	×	×	-
P4P	✓	✓	✓	✓	✓	✓	+



https://policyexchange.org.uk/wolfsonprize/

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