Road charging for cars

What the European Commission should do

May 2017

Summary

The European Commission is scheduled to review the Eurovignette Directive, with its new proposal expected in May 2017. This directive sets out the framework that EU member states have to follow when designing national road charging schemes. The extension of road tolls to passenger vehicles has long been discussed but was placed high on the EU agenda following German plans to introduce the "PKW-Maut". Experience from truck tolling demonstrates that tolls are an efficient means to reduce air pollution, GHG emissions, and congestion. Truck tolls raise significant funds for a country's public budget but do not have negative economic impacts [1].

Road charging based on distance is a smart and effective instrument that will play an increasingly important role in European transport policy:

1. It complements fuel taxation: the uptake of more efficient and electric vehicles will drastically reduce fuel tax revenues. Road charging can raise additional revenues while contributing to further reductions of CO2 emissions necessary to achieve Europe's climate targets.
2. It can improve air quality: toll differentiation (as is now mandatory for trucks) stimulates the uptake of cleaner, newer vehicles. Tolls are also an effective means to improve the efficiency and choice of transport, which can reduce air pollution and noise.
3. It is essential to help deal with new demand patterns: electric, shared and autonomous vehicles will considerably decrease driving costs, make driving more attractive and, without accompanying measures, could lead to more miles travelled. Road charging based on distance can effectively manage increasing demand for driving.
4. Road charging can be fair and progressive if implemented in the right manner: paying as you drive is in line with the user pays, polluter pays principle. It is also not necessarily regressive. Smart use of revenues can ensure that low-income groups are not made worse-off.
5. It tackles congestion: traffic jams reflect inefficient use of roads. Road charging can be differentiated by time and place to reduce congestion much more (cost-) effectively than constructing new roads, which only leads to more demand for road transport.
6. Setting up charging schemes across Europe would spur innovation in technological solutions necessary to enable tolling, giving opportunities for EU suppliers and ICT companies to lead and benefit economically. EU action would also ensure that non-nationals are not discriminated against. The EU should also make the Connecting Europe Facility (CEF) funds available for member states to invest in the rollout and maintenance of tolling technology and infrastructure.

An EU framework will ensure the effectiveness and cost-efficiency of the schemes across countries. EU action is crucial to protect the internal market and give guidance to national authorities, avoid proliferation of distortive and incompatible schemes, and prevent discrimination against foreigners.

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TRANSPORT & ENVIRONMENT

Therefore, the EU should:

1. Mandate manufacturers to fit "one box" technology into new cars which includes basic components that provide different ITS applications, including the capabilities required for GNSS based tolling. Certifying and fitting this technology as standard would lead to significant cost reductions, facilitate the uptake of road charging and create additional business opportunities, contributing to the development of ITS applications. Most importantly it would significantly reduce the introduction costs of road charging for passenger cars, providing genuine added value to member states that consider opting into the EU road charging scheme.
2. Within the Eurovignette Directive, provide guidelines and minimum harmonised standards for setting up and implementing national road charging schemes within Europe. This would encourage charging based on distance travelled, and differentiated by CO2, air pollutant emissions and congestion. This would be based on a common structure of non-discriminatory rules tailored to social needs. The guidelines should focus on ensuring non-discrimination and not restrict member states' freedom to tailor tolls to national (or regional and local) circumstances.
3. Protect the privacy of users from a legal perspective. Technology should ensure data protection ("privacy by design") and a legal framework should be put into place defining minimum data required for road charging, similar to eCall.

Now is the time to develop a framework for distance-based road charging for all cars on the entire road network. Distance-based charges can play a role in addressing a variety of issues in one single instrument: it can tackle CO2 emissions, pollution and congestion while raising revenues, as explained in detail below.

1. Road charging for cars in Europe

1.1. Current situation

Road charging involves vehicle users paying for their use of road infrastructure. The set-up of the scheme can take very different forms as the area covered by the scheme can vary from urban centres to motorways to the entire road network. Pricing can be flat, time-based or distance-based. Furthermore, tolls can be differentiated by the vehicle's characteristics, location and time of day to take into account CO2 emissions, air pollution, noise, and congestion.

In Europe, many of the road charging schemes rely on vignettes. This is the case in eight member states [2] that charge for the use of roads in advance for a fixed period of time (common periods of time are 10 days, monthly or annually). Ten member states charge road users based on the distance driven. These types of schemes are usually applied to motorways only, to raise funds for road construction and maintenance (road tolls).

The situation is very different for Heavy Goods Vehicles (HGV) [3]. Only four member states do not have any kind of road charging scheme and those which had vignettes are shifting to electronic distance-based road charging [4]. Currently, eight member states have electronic network wide distance-based schemes with Belgium the latest to join the group in 2016. The Eurovignette Directive defines how such tolls can be structured. Currently, the toll can be based on infrastructure damage, which is differentiated by vehicle weight, EURO class, and time of day. Additionally, trucks can be charged based on certain external costs; namely air pollution and noise. The maximum amounts are defined in the annex of the Directive.

There is no similar framework for cars. Currently, the Commission only monitors these schemes and ensures that the Treaty principles of non-discrimination and proportionality are respected. However, the Transport Commissioner Violeta Bulc has voiced support for a standardised Europe-wide road-charging scheme for both HGVs and cars that should be based on distance travelled on numerous occasions. The upcoming review of the Eurovignette Directive provides a perfect opportunity for this.

1.2. Why vignettes are not the right instrument

Vignettes entail paying for road use based on time but the link between time and road use is very weak and fails to incentivise behavioural changes. After buying a vignette, road users can drive as much as they want during that period of time, which means that for the same vignette there will be drivers who actually use the roads more than others, although they pay the same.

Vignettes also fail to manage road transport demand. Paying for road use based on time does not create the incentives to adjust driving taking into account the costs imposed on infrastructure. The logic behind the scheme is instead counterproductive: to maximise their value, vignettes can actually promote further road use. They are also not able to take into account external costs which vary with location, such as air pollution and congestion.

On top of that, vignettes are also more likely to be discriminatory for occasional users. Short-term vignettes tend to be disproportionately more expensive than long-term vignettes. At the EU level, this poses a serious issue because short-term vignettes are typically bought by foreigner drivers.

Charging for the use of roads can instead be done in a distance-based manner, which makes frequent users pay more and provides incentives for cleaner and more efficient road use. While not a replacement for effective fuel taxes at national level, road charging is in line with the principles of “user-pays” and “polluter-pays”, distance makes for a better link with road use.

2. Why should Europe move towards distance-based road charging?

Transport will look very different in the coming decades. If we are to tackle growing emissions from the sector then changes are badly needed. Transport is now the largest contributor of CO2 emissions in the EU. The upcoming trends of vehicle autonomy and electrification of transport will transform demand patterns and impose additional burdens on infrastructure. Congestion is already a huge problem and is expected to worsen with increasing urbanisation. Air pollution, noise and other externalities associated with car use are a persistent issue and result in massive health costs every year.

Now is the time to develop a framework for distance-based road charging for all cars on the entire road network. Distance-based charges can help address a variety of issues in one single instrument: it can tackle CO2 emissions, pollution and congestion while raising revenue for a country’s public budget.

2.1. It complements fuel taxation in a context of transport decarbonisation

The EU has set targets to prevent dangerous climate change. It committed itself to reduce CO2 emissions by 80-95% by 2050 (compared to 1990 levels) [5], which means that practically every sector in the economy will have to reduce its emissions to almost zero. It will require abatement efforts from transport, which represents over one quarter of total GHG emissions in the EU [6]. Within the sector, light-duty vehicles [7] are the main GHG emitters, being responsible for 13.5% of all GHG emissions [8].

By 2030, emissions in the transport sector are expected to decline by 20-30% as a result of a range of policies and measures at both national and EU level [9]. These reductions will be mainly achieved through lower fuel use, which will critically reduce fuel tax revenues in member states. A back-of-the-envelope calculation performed by T&E shows that fuel tax revenue in Europe can be 40 billion euros lower in 2030 than revenues in 2010, and this is considering a business-as-usual scenario in 2030 [10]. If more stringent standards are implemented by 2030 (as will have to be to achieve EU's decarbonisation targets [11]), this will imply a further 17 billion euros in losses in 2030 (comparing with a business-as-usual scenario) [12].

Due to political sensitivity, national governments have been reluctant to raise fuel taxes to effectively mitigate road transport's effects on public space and environment. In its 2015 study [13], Transport & Environment showed that in real terms fuel taxes have decreased over the years. In 2014, the average road fuel tax paid by motorists and hauliers, excluding VAT, was €0.52 which, corrected for inflation, is 20% below the 2000 level of €0.64/l. This surprise finding can be explained by: 1) inflation eroding nominal tax rates; 2) a shift from petrol to lower-tax diesel fuel; and 3) diesel tax rebates for trucks that have been introduced by eight countries over the past 15 years.

Fuel taxation plays important roles in the economy. Besides contributing to reducing CO2 emissions and oil dependency, fuel taxes are an important source of revenues for governments. In the EU, revenues from fuel tax represent 0.3% of GDP, on average [14]. Without this source of revenue, the state's capacity to fulfil its obligations (for example education, health care, pensions) to citizens will be reduced. Whilst increasing fuel tax increases could initially offset lower demand (and thereby accelerate the transition to e-mobility), fuel tax revenues will ultimately become a marginal source of income in a decarbonised economy. Taxes could be raised from other sectors to compensate for the revenue losses, but this could cause significant distortions in the economy. Depending only on fuel taxation and other existing taxes, transport will end up a receding source of tax revenues, shifting the burden to raise money for the public budget to other sectors.

Road charging can complement fuel taxation and raise revenue while contributing to additional CO2 emissions reductions. The latter can be achieved by making drivers aware of the true costs of a car trip. Car users tend to overlook incremental or invisible costs (such as maintenance costs) and don't usually take into account other burdens that car use imposes on society, such as CO2 emissions, air pollution, and congestion. They also create routines around car use which makes it very difficult to change [15]. The use of the car becomes commonplace, leading people to choose driving over other transport modes without considering the full cost, and cars end up being used more than necessary. Road pricing based on distance travelled can link driving decisions to the real costs of driving. This will lower excess driving demand and shift mobility to other modes of transport, reducing overall CO2 emissions.

Further reductions can be achieved when distance-based road charging is differentiated by CO2 emissions. For the same distance travelled, CO2 differentiation makes the driving of polluting cars more expensive, encouraging the purchase of more fuel efficient vehicles and thereby lowering CO2 emissions.

Studies analysing the implementation of a nationwide distance-based road charge on passenger cars in the Netherlands and in Finland [16] predict a 4% to 14% decrease in CO2 emissions by 2030 compared to a business-as-usual scenario. This shows how distance-based tolls can play a role in decarbonising transport. They are not a silver bullet though and would have to be complemented by other policies as part of any political attempt to transition to cleaner transport.

2.2. It deals with new demand patterns in road transport

As the use of more fuel efficient or electric vehicles increases in Europe, the costs of using the car will fall, making driving more attractive. For existing users, lower costs encourage longer or more frequent trips, while for new users driving becomes a new possibility. The rebound effect of improved fuel efficiency could further lead to more driving which will partly offset emission reductions, although not enough to completely eliminate efficiency gains [17].

Another crucial trend which will transform the road transport sector is vehicle autonomy. Autonomous vehicles impose fewer restrictions on driving and can literally mean driving all day and all night. Other driving costs (time spent driving, drivers' costs) will also significantly decrease. This could result in increased use of road transport. A recent ITF study [18] on shared self-driving vehicles showed that although the number of cars is expected to decrease significantly with the increasing uptake of autonomous ride- and car-sharing in cities, vehicles-kilometres driven will actually increase.

Overall, improvements in vehicle efficiency and the shift to zero emission mobility will be positive for the climate but the societal benefits could be far greater if rebound effects are limited. A greater issue is both shared and autonomous cars, which could lead to substantial additional driving if no counteracting policy to manage demand or perverse incentives is put in place (e.g. it might be cheaper to cruise around city centres instead of paying for a parking spot, thus adding to congestion and possibly pollution).

All these trends leading to additional driving put further burden on infrastructure. They aggravate congestion problems and reduce throughput of traffic, imposing costs on society. Fuel tax is not effective at dealing with these problems as it has only an indirect link with distance travelled and cannot be differentiated by time and place to address congestion problems. Road charging, on the other hand, is a very effective demand management tool to deal with increased road use. It can account for infrastructure use and be differentiated to internalise the external costs of driving.

2.3. It reduces air pollution and noise

Cars facilitate mobility and play an important role in the economic development and social fabric of Europe, but they also impose substantial costs. Besides private user costs such as fuel and maintenance, there is another category of cost denoted externalities, which affect not only the driver who causes them but society as a whole. These include accidents, air and noise pollution costs, in addition to the already mentioned CO2 emissions costs. The driver tends to underestimate or completely overlook these external costs when making driving decisions, which leads to more driving than the socially desirable level.

The problem is greatest for diesel cars. They currently do not have the incentives in place to address the burden they impose on society. The problem has been paid particular attention in the recent/ongoing Dieselgate scandal that erupted following the VW emissions cheating uncovered by the US authorities in autumn 2015. Numerous investigations into diesel emissions have since confirmed that a vast majority of carmakers abuse the current

legislation on pollution limits and switch off emission control in many on-road conditions, resulting in significant exceedances of dangerous pollutants when in use. Transport & Environment has analysed [19] the available test results to show that at least 29 million grossly polluting Euro 5 and 6 diesel vehicles are currently in use in Europe and will remain a pollution legacy for years to come. Currently there is no EU-wide scheme to tackle the impact of diesel pollution coming from vehicles and a distance-based framework could be an effective measure to address that. The scheme would have to take into account the age of vehicles as well as their emissions in real use as the evidence is becoming more and more encompassing and reliable.

The case of petrol cars requires careful consideration. Although studies show that petrol cars cover their costs in rural areas, this internalisation is based on fuel taxes, in many cases the only variable charge implemented. However, fuel tax is weakly linked to the emission of air pollutants, noise levels and the associated health effects, and therefore is not an effective instrument for internalising localised externalities. The impact of air pollution depends not only on the level of emissions but also the level of dispersion and exposure to those pollutants, which varies by region (traffic conditions, population, etc). Similarly, impacts of noise on health also depend on level of exposure conditional on region and traffic volumes. Noise also causes disturbances, which represent a higher burden during nighttime than during the day. These variations by time and location require an instrument that can be accordingly differentiated, such as road charging.

Full internalisation requires externalities to be taxed as close as possible to their source. The structure of road charges should reflect the structure of costs caused by driving. Otherwise, drivers do not face the right incentives to change their behaviour, and as a result, roads are not used efficiently. By internalising these costs, road pricing will reflect the true costs of driving and thereby promote a more efficient use of the road network. It can reflect the cost structure and be differentiated to account for localised external costs. Incentives to reduce air pollution require differentiation by euro class, fuel type and region, and internalisation of noise costs should incorporate differentiation by time of day, noise emission class and region.

Whether or not external costs can be considered to be fully internalised or not depends heavily on assumptions. For example, calculations are extremely sensitive to the cost of CO_2. This is why strict adherence to the principle of "internalisation of external costs" may be too narrow. Indeed, regardless of the internalisation methodologies road pricing is a useful instrument to raise revenues, manage traffic and reduce pollution.

2.4. It tackles congestion

Congestion is a massive problem in parts of Europe. Every day, millions of drivers waste their time in traffic jams, especially in and around urban areas, which represents significant costs in terms of delays, additional fuel consumption and the associated environmental impacts. Each year, congestion costs in Europe amount to €100 billion, about 1% of the EU's GDP [20]. Without effective action, the problem could worsen, with congestion costs projected to increase to €200 billion by 2050 [21].

Congestion is an inefficient use of road space, which results from drivers neglecting the impact of their transport decisions. While drivers take into account their own costs, they do not consider the costs they impose on others. Given the limited capacity of the road network, each additional car on the road decreases the overall traffic speed, reducing traffic throughput and creating traffic jams. The notion that expanding road infrastructure is a means to tackle the problem has long been disproven by the impact of induced demand.

Road charging can effectively tackle congestion. Charging a higher fee during peak times and in particular congested places can align driving decisions with the costs imposed on all road users. It contributes to changes in behaviour,

both on the short-run, by influencing decisions about the number of trips, time of the day, route and mode of transport, but also in the long-run, by influencing housing and employment decisions. It can be incorporated in distance-based road charges through time and location differentiation as smart technology allows for flexible charging based on time of the day or year, particular road conditions or any temporary adjustments.

In urban centres, congestion charges are already a reality. In Europe, several cities implemented congestion charging schemes [22] which have successfully lowered congestion: the number of vehicles entering the charging area decreased by 21% in London, 28.5% in Milan and 29% in Stockholm. The case of Milan is particularly revealing [23]. Implemented in January 2012, the scheme was temporarily suspended for 8 weeks in July-September 2012. The day following the court decision traffic increased immediately. The suspension lead to approximately 27,000 additional entries in the previously charged area, which represents an increase of 14.5% of both charged and exempted vehicles [24].

Road charging is not only very effective at managing congestion but may also be the *only* effective measure. Another theoretical option to deal with congestion is the construction of new roads to expand the capacity of the network. However, evidence [25] shows that additional traffic will be generated as a response, quickly filling up the new roads and offsetting capacity increases. New space will be used up by drivers because the increased capacity improves travel reliability and reduces travel times, making driving more affordable ("induced demand"). Only a demand-side policy such as road charging can prevent increasing congestion problems and promote alternative modes of transport.

2.5. Road charging is fair if correctly implemented

Distance-based charges are considered to be a fairer form of road pricing to the extent that they make road users pay for the costs they impose on the infrastructure (user-pays principle) as well as pay for the externalities they create (polluter-pays principle).

There are some concerns about the distributional effects of distance-based charges. Evidence [26] is mixed but it seems road charging is not necessarily regressive. In Stockholm the congestion charging scheme was found to be progressive [27]. For nationwide road charging schemes, there is no scheme in place but the Netherlands and Finland have considered the possibility [28]. The Finnish study concluded that the new kilometre fee would reduce the tax burden on all income groups compared to the current tax regime. They also note, however, that the abolishment of fixed taxes will make heavier cars cheaper, which will be more beneficial for the wealthier groups. Regarding the Dutch study, Cost-Benefit Analyses have been performed and are overall positive [29].

Whether road pricing is regressive or progressive depends on the circumstances but the use of revenues can ultimately ensure that the scheme is progressive. Road pricing is progressive in the sense that wealthy people drive in general more and therefore would pay more for the use of roads. However, it can also have regressive effects if it prevents the lower-income groups from making as many trips as before or makes them pay more as they tend to live farther away from urban centres and need longer commutes to go to work. Even if this is the case, groups at disadvantage can be compensated through revenue redistribution or discounts and exemptions. The additional revenue raised allows governments to reduce other taxes (such as labour taxes) and lower economic distortions. Revenue can also be invested in developing public transport, a close substitute of car use.

The reduction of air pollution also makes road charging more progressive. Air pollution tends to affect more the poor which usually live closer to major motorways and roads and thereby are more exposed to dangerous traffic. By reducing externalities, road pricing is more beneficial to these people. In London, the congestion charging scheme marginally reduced inequalities in air pollution exposure [30].

2.6. Road charging for trucks is a success

Distance-based charging has been proven to be the most effective means of tolling trucks for their use of road infrastructure. In 2014, the Commission published an evaluation on the impact of EU infrastructure charging policy since 1995 [31]. This report detailed how time-based or "vignette" systems are an inferior means of charging.

Distance-based tolling is a better reflection of actual infrastructure use and all trucks are charged based on kilometres driven rather than on how often they enter a country. Vignettes are not effective instruments for achieving environmental improvements or managing traffic flows. If a country wants to use tolls for reducing air pollution, congestion, or greenhouse gas (GHG) emissions, then distance-based charging is the means to do so.

The German case is particularly revealing. Germany introduced the LKW Maut in 2005. Since then the system has greatly increased the uptake of the cleanest trucks by differentiating tolls based on EURO class. This has a positive impact on air quality. Furthermore, the fact that tolls reflect kilometres driven means that logistic efficiency is improved as freight companies want to make the most of every transport operation. Trucks can drive empty without any additional cost in countries that apply vignette systems. Distance-based systems promote smarter transport behaviour. Moreover, the German LKW-Maut raises considerable revenues (around 4BN per year) without negatively impacting the economy or the logistics sector.

3. Why is an EU framework necessary?

Following the German case of a national road toll being incompatible with EU law and discriminatory to non-German drivers, it is clear that - in light of vehicle pollution, climate targets, and declining fuel tax revenue - more member states in the future may opt for introducing road tolls for light-duty vehicles without consideration of EU-wide ramifications. To pre-empt a proliferation of divergent schemes that might distort the single market and be costly, it is imperative that the Commission introduces an (optional) EU-wide framework of key principles to be adhered to in any future road tolling schemes.

Many European countries struggle with declining fuel taxation revenues and worrying levels of air pollution and noise. These problems are common to all 28 member states and would greatly benefit from a joint approach. Distance-based road charging can address these issues but it will be more effective if a harmonised scheme is implemented across Europe. A common EU framework will ensure the well-functioning of the internal market and reduce the risk of discrimination. It will facilitate the implementation process, significantly reducing costs and generating additional benefits for Europe.

Setting up a nationwide scheme requires the implementation of a technology that monitors traffic flows, registers distance driven, applies the charges and controls payments. It will involve a range of stakeholders, including road operators, toll chargers and European Electronic Toll Service (EETS) providers for all 28 member states. Failure to reach common standards for communication between cars and back office, and interoperability between technologies at the EU level will create barriers to the operation of the internal market. If each member state implements its own independent scheme, the mobility of people between EU countries will be considerably hindered.

It will also increase costs for governments, businesses and citizens. Road users would have to own a road charging device for each country they drive through and hold several contracts for every scheme implemented, increasing significantly the burden to drivers of such schemes. It will also raise significant challenges for the charging of foreign

cars and increase the risk of discriminatory charges. Manufacturers of the technology would also not benefit from wide scale deployment, missing an opportunity for decreasing production costs.

EU action on common standards would achieve significant cost reductions but also create new business opportunities. Linked to ITS developments, road charging can be facilitated and foster the development of vehicle connectivity in Europe. Many key technology components are common (satellite positioning, communication channel, vehicle-to-infrastructure communications, etc) and can be aggregated to provide several functions and create a multi-service platform. This will further lower costs and foster innovation in Europe.

Furthermore, the EU Commission will present the European budget for the post-2020 seven-year period before 01 January 2018. This budget could earmark some transport spending for the establishment of tolling technology. Such financial support for tolling infrastructure would reduce the burden of the initial financial investment required to establish tolling infrastructure in member states where price is a clear bottleneck to the deployment of road charging.

An EU framework for network-wide distance-based road charging is necessary for ensuring non-discrimination, technical standards, interoperability of technology and protection of privacy. These issues will be further developed in the following section.

4. What should a distance-based road charging scheme in Europe look like?

The distance-based road charging should be tailored to local conditions and needs, but the design of the scheme should follow common guidelines defined at the EU level to ensure a harmonised approach to road charging that supports the internal market and guarantees non-discrimination of foreign drivers.

These guidelines should encourage member states to implement road charging for cars on the entire road network, based on distance driven. Existing vignettes (time-based road charges) should be phased-out as they fail to provide incentives to improve efficiency of road use. To tackle some of the costs generated by driving, the EU can provide non-binding guidelines on the structure of charges, encouraging differentiation by air pollution, congestion, CO2 emissions, and noise.

The technology used for charging the use of roads is a critical factor for the implementation of the scheme. It influences the feasibility and user acceptance of the scheme since it has important implications in terms of ease of use and privacy protection. Interoperability between technologies as well as enforcement at EU level must be ensured to support free movement of cars in Europe and prevent discrimination of non-national drivers.

T&E commissioned a study by TNO [32] to assess different technology options for road charging of cars. Several technologies can be used for Electronic Toll Collection (ETC). The system needs to be able to measure road use: it should register distance travelled and, in more advanced systems, identify road type, location and time. Technologies for road use measurement are divided in two main groups: those which require roadside equipment, based on Vehicle-to-Infrastructure (V2I) communications, and those which are installed only in the car (or smartphone), based on satellite positioning technologies. In the case of in-car technologies, the system must also include a communication channel to transmit the collected information to a back office for charging purposes. To ensure compliance, the system also includes infrastructure for monitoring and enforcement of road charging. TNO produced relevant

conclusions on the technology options for nationwide road charging of cars in Europe, which will be summarised in the following sections.

4.1. GNSS-based road charging in Europe

TNO conducted an extensive evaluation of the main technologies used for road pricing and concluded that the most appropriate for a nationwide distance-based scheme is an in-car technology based on GNSS (Global Navigation Satellite System). A 2004 study commissioned by the European Parliament [33] also supports this conclusion, indicating that the implementation of a scheme on the entire road network for all vehicles requires a more flexible technology such as GNSS-based tolling.

The majority of the member states which have a distance-based scheme in place have opted for the GNSS technology [34]. Technically, it would be possible and relatively easy to enlarge these schemes to include cars, by installing OBUs on cars and expanding the operations of the back office. Furthermore, such a system could be linked to smartphone apps which some toll operators are already developing. GNSS technology is also compatible with DSRC-based systems, which has the advantage of not making existing DSRC systems obsolete. The opposite does not hold true, which makes GNSS a very interoperable technology.

GNSS-based road charging is also more appropriate for a scheme that covers all roads. Unlike DSRC-based systems, it does not require large investments in roadside equipment and is more flexible, being easily expanded to other roads (only needs software update). The GINA project, sponsored by the European Commission and the GNSS Agency (GSA), concluded that the more complex is the road charging scheme, the less cost-effective are DSRC and ANPR (Automatic Number Plate Recognition) but the costs of GNSS do not rise as rapidly [35]. After implementation, GNSS-based road charging generates lower operating costs, which is essential when considering nationwide implementation that includes roads with low traffic volume and thereby low revenue potential.

Road charging on the entire road network also requires very accurate positioning data and identification of roads to which the full deployment of Galileo after 2020 will significantly contribute.

A GNSS OBU is, however, more expensive than a DSRC OBU, but costs are declining because of developments in Intelligent Transport Systems (ITS) applications. These are based on vehicle connectivity and GNSS and include eCall, telematics, Usage-Based Insurance (UBI) and other Event Data Recorders.

The creation of “one box” fitted during the manufacturing process which aggregates all applications based on the same components (GNSS, communication channel, DSRC) can further reduce costs and create a multi-service platform for ITS applications. This should be an open platform to allow different developers to participate, but at the same time it should ensure car safety and security. The European Parliament’s study claims that such a box could deliver significant cost reductions, requiring an investment of €100 with operational costs of less than €10/month. Questions of ensuring that payment is possible even when the battery is empty also need to be addressed but such problems are technically possible to overcome.

The afore-mentioned Finnish study [36] also considered the possibility of private service providers offering additional services to road users on top of road charging (multi-service model). It estimates that this model will increase investment costs (mainly due to higher project costs associated with the need to manage more contracts) but operating costs will be lower as the necessary information for road charging is collected by the private service provider. What is more, the study indicates that operating costs could be further decreased if private service providers were allowed to collect charges and invoice users (under Finnish law, taxes can only be collected by public

authorities). For road users, the costs of acquiring or renting an OBU also decreases if provided by a private company which can significantly reduce cost by offering additional services.

The Commission should not only set interoperability standards (discussed below) but it should also consider mandating the essential capabilities to enable GNSS-based road charging for all new cars. By fitting certified technology as standard the EU could greatly reduce the introduction costs of road charging schemes at national level. The additional cost for manufacturers would likely be limited since much of the necessary technology is already fitted to new cars. The main challenge would then be to certify this technology for tolling use.

4.2. Interoperable system at EU level

When implemented, most road charging schemes are interoperable within the national territory but not necessarily at the EU level. Failure to achieve interoperability of the electronic road toll system in the EU creates significant barriers to cross-border traffic and the internal market. A fully interoperable road charging scheme at the EU level requires interoperability of technologies (technical interoperability) but also compatibility between procedures and contracts such that any driver only needs one contract to be able to use any charged road in the EU, and toll charges can easily exchange information and enforce charging in their territory.

To guarantee interoperability of electronic road toll systems in the EU, the EETS Directive (Directive 2004/52/EC) was adopted in 2004, establishing a common framework for addressing barriers to mobility and promoting the principle of "one vehicle, one contract, one OBU". It was followed by the EETS Decision (Commission Decision 2009/750/EC), defining an EETS which complements services at national level, facilitating charging of roads used by non-nationals.

The EETS legislation has largely failed to achieve interoperability across the EU. The causes behind are not so much technical. Interoperability can be achieved between different technologies (GNSS and DSRC, although only in one way) and across member states by the defining communication standards (EU standards for DSRC already exist). The issue that is preventing full interoperability at EU level is the lack of business case for EETS providers. The current set-up puts an immense burden on the EETS provider. The transfer of technical and operational risk to EETS providers and uncertainty about revenue generation is compromising the deployment of EETS.

It is not sufficient that technology is interoperable, but each OBU/app should also be able to adapt to the different scheme design and tariffs of each country. It may be necessary to implement necessary software in the OBU/app or back office to be able to calculate the chargeable amounts accordingly, which puts additional burden on the EETS provider.

To address these issues, the EU is planning to review the EETS legislation in 2017. The update should stimulate commercial deployment of EETS by decreasing the risk of EETS providers. As for DSRC, standards for GNSS should be agreed. There is also an opportunity to enhance the synergies between electronic tolling and other ITS applications that use the same technologies.

4.3. Data protection and privacy

Issues surrounding privacy protection of road charging are crucial for the successful implementation of the scheme. GNSS-based tolling, in particular, involves collecting large amounts of data about the position of the vehicle and possibly in real-time, uncovering individual movements. This is very sensitive information and its protection is essential for an adequate deployment of road charging in Europe.

Privacy can be ensured by the technology itself ("privacy by design"). The system can be designed to ensure the highest level of protection, through encryption or minimising the time that data is stored, for example [37]. A thick OBU also ensures higher privacy protection by limiting the access to position information and providing only the aggregated data for charging.

A legal framework to guarantee data protection is equally necessary. Similar to eCall [38], privacy requirements should be determined, establishing the minimum information that should be made available to enable road charging, who should have access to that data and for how long it should be stored. In the case of eCall, personal data collected cannot be used for any other purpose and cannot be exchanged with other systems that provide private or added-value services. If the same rules are applied to road charging systems, this will have implications for the generation of additional benefits through the link with other ITS applications. Authorities who have assessed the implementation of a road charging scheme expressed concern over the use of information collected for tax purposes for commercial applications.

5. Conclusions and policy recommendations

Transport will look very different in the coming decades. Coupled with other measures at EU and national level, distance-based charging is an effective means to positively influence how people move around. Kilometre-based road charging can reduce air pollution, greenhouse gas emissions, congestion, and noise. Furthermore, the reduction of revenues from already insufficient fuel taxes that comes as a result of decarbonisation will mean that countries will need to rethink how they tax transport. Distance-based is an effective means of securing revenue for a country's public budget and is far more efficient than time-based systems.

Now is the time to introduce distance-based road charging for passenger cars and vans covering the entire road network. Previous experience with heavy-duty vehicles shows that time-based tolls, i.e. vignettes, are ineffective, and only distance-based charges, in line with the "user/polluter pays" principles, can help manage new demand patterns and steer behavioural change in the right direction.

Differentiation based on emissions and demand patterns is an essential element of such tolling systems to align incentives and ensure efficient road use. Road charges can be differentiated to promote smarter transport behaviour and the uptake of cleaner vehicles. This is dependent on the structure of the charging system and also requires further policy to complement the toll in order to incentivise cleaner transport.

To avoid distortion of the EU single market and ensure harmonised implementation of distance-based road charging in Europe, the Commission in its upcoming review of the Eurovignette Directive should ensure a level-playing field and non-discrimination of EU citizens by establishing a common policy framework for the road charging of light-duty vehicles in Europe and harmonising key aspects of the scheme. This will bring down costs by stimulating harmonised technological solutions and resulting economies scale. It should encourage the implementation of a distance-based charge for the entire road network as the most effective means of raising appropriate revenue and encouraging behaviour change in line with proportional road use.

Common principles should include:

- Open framework that sets minimum standards but allows member states to go beyond by setting more ambitious schemes.
- Tolls based on distance travelled, without discrimination of outside drivers or distortion of the EU single market.

- Distance-based fares should be differentiated by vehicle emissions (CO2 and air pollutants) and noise pollution; these could be further developed to apply flexible charges based on congestion or other traffic conditions to incentivise more efficient transport systems.
- Special attention should be given to sensitive social groups as well as areas where replacement of travel modes (public transport or rail) is not sufficiently developed.

While it is not the role of Transport & Environment to advise on the single technology solution to be mandated, and further research and discussions with all stakeholder (e.g. electronic toll operators) should be encouraged, the study we have commissioned has concluded the following as regards the practical way forward for distance-based tolling:

1. Promote GNSS-based tolling for all new cars. It is the most flexible and advanced technology in the market. It can be easily scaled to include other roads and it is cost-effective for a scheme that covers all roads, including those with low traffic volumes.
2. Consider mandating the fitting of "one box" which includes basic components that provide different ITS applications, including GNSS-based tolling. Certifying and fitting this technology as standard would lead to significant cost reductions, facilitate the take-up of road charging and create additional business opportunities, contributing to the development of ITS applications. Most importantly it would significantly reduce the introduction costs of passenger car road charging, providing genuine added value to member states.
3. Ensure interoperability of schemes between member states by strengthening the EETS legislation and defining standards for GNSS-based tolling. Technical interoperability has been largely achieved (especially if considering GNSS-based tolling) but administrative procedures and service provisions still need to be harmonised to fully deploy EETS. The large amount of information (28 different scheme designs) and uncertainty about revenue generation put huge risk on the EETS provider. Legislation should ensure that burden is shared between stakeholders.
4. Guarantee the protection of data for road charging. Privacy should be incorporated into technology ("privacy by design") but also ensured by a legal framework that defines minimum information required for road charging, similarly to eCall.

Many European countries struggle with declining fuel taxation revenues and dangerous levels of air pollution and noise. These problems are common to all 28 member states and they would greatly benefit from a joint approach. Distance-based road charging can address these issues but it will be more effective if a harmonised scheme is implemented across Europe. A common EU framework will ensure the internal market functions well and reduces the risk of discrimination. It will facilitate the implementation process, significantly reducing costs and generating additional benefits for Europe.

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[1] See https://www.transportenvironment.org/sites/te/files/publications/2017_04_road_tolls_report_briefing.pdf
[2] See http://ec.europa.eu/transport/modes/road/road_charging/doc/pv_charging.jpg
[3] See http://ec.europa.eu/transport/modes/road/road_charging/doc/hgv_charging.jpg
[4] Ricardo AEA, 2014. Evaluation of the implementation and effects of EU infrastructure charging policy since 1995. Final Report. European Commission
[5] European Commission, 2011. COM(2011) 112: A Roadmap for moving to a competitive low carbon economy in 2050.
[6] EEA GHG Viewer, 2012 emissions data
[7] Includes passenger cars and vans
[8] European Commission, 2012. SWD(2012) 213: Impact assessment accompanying proposals to amend Regulation (EC) No 443/2009 and Regulation (EU) No 510/2011.
[9] See T& E study on how to meet the 2030 targets for more information:
http://www.transportenvironment.org/sites/te/files/2015%2006%20ESD%20Paper_June.pdf

[10] Fuel tax revenue losses are estimated based on the level of CO2 emissions in 2010 and 2030, taken from the European Commission's 2030 reference scenario (available here). Contribution of cars to the emissions level is based on their share of total energy demand in transport. Contribution of vans is assumed to be neutral: use of vans will increase between 2010-2030 but they are also expected to become more efficient – the two effects are considered to offset each other. A further split must be done between petrol and diesel vehicles because the tax rate of the two fuels is different (rate used is weighted average for EU28 in 2014 euros for 2030, assumed to be stable in the period analysed - based on T&E's fuel tax report). Vans consume only diesel. Cars use both fuels: the split is based on the Commission's reference scenario for 2010 and 2030 (energy consumption shares by fuel type are converted to fuel consumption shares). Emission factors to convert CO2 emissions into fuel consumption are retrieved from DEFRA (a weighted emission factor is used for cars).

[11] T&E's Road to 2030: how EU vehicle efficiency standards help member states meet climate targets : http://www.transportenvironment.org/sites/te/files/2015%2006%20ESD%20Paper_June.pdf

[12] The estimation method is similar to the one described in endnote 10. Additional CO2 reductions in 2030 are based on new CO2 standards for cars and vans (70gCO2/km for cars and 100gCO2/km for vans in 2025, and 55gCO2/km for cars and 70gCO2/km for vans in 2030, see T&E's Road to 2030 paper for more information – https://www.transportenvironment.org/sites/te/files/2015%2006%20ESD%20Paper_June.pdf)

[13] See https://www.transportenvironment.org/sites/te/files/publications/2015_10_Europes_tax_deals_for_diesel_FINAL.pdf

[14] Eurostat (online data codes: gov_a_tax_ag), excise duties 2012 for EU27.

[15] European Commission, 2009. Designing policy to influence consumers - Briefing note 4: consumers and their cars

[16] Both schemes propose kilometre-based fees, varying according to level of CO2 emissions and location, which would substitute fixed motoring taxes but complement the existing fuel taxes. Plans and studies conducted in the Netherlands (NL), Finland (FI) and Belgium (BE). NL: Geurs , K., Haaijer , R. and Meurs , H., 2010. The Dutch national kilometre charge: impacts on the Dutch car market and environment; FI: Ministry of Transport and Communications, 2014. Fair and Intelligent Transport. Working Group Final Report; BE: Mayeres, I., 2015. Road charging in Belgium: opportunities and latest state of play. VITO

[17] Rebound effects are found to be relatively small: "The literature review concludes that the elasticity of fuel consumption with regard to fuel price is between -0.25 (short term) to -0.6 (long term). As a result a 27% improvement of fuel efficiency, associated with the step from 130 g/km to 95 g/km leads to a net reduction in CO2 emissions of 22.1% (ST) and 15.2% (LT) due to the rebound effect of lower cost of fuel" in http://ec.europa.eu/clima/policies/transport/vehicles/cars/docs/study_car_2011_en.pdf

[18] ITF, 2015. Urban Mobility System Upgrade: How shared self-driving cars could change city tra-ffic.

[19] See http://www.transportenvironment.org/publications/vw%E2%80%99s-cheating-just-tip-iceberg and https://www.transportenvironment.org/sites/te/files/publications/2016_09_Dieselgate_report_who_what_how_FINAL_0.pdf

[20] European Commission, 2007. COM(2007) 551: Green Paper - Towards a new culture for urban mobility.

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[28] See endnote 12 for more information
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[35] Geurs , K., Haaijer , R. and Meurs , H., 2010. The Dutch national kilometre charge: impacts on the Dutch car market and environment.
[36] FI: Ministry of Transport and Communications, 2014. Fair and Intelligent Transport. Working Group Final Report.
[37] The European Parliament (2014) suggests ways in which technology can address privacy concerns, on page 42: Spitscoren (2009), Spitsvrij (2012), Numrich et al. (2013).
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Further information

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