Integrated Fuel and Car Use Taxation by Satellite Tracking

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Abstract

This paper considers alternatives for taxation of car use. First, the analysis is focused on the taxation of Finland. We present and compare three main alternatives: 1. the current car taxation system of Finland, 2. a km-based taxation system presented by the working group commissioned by the ministry of transportation and 3. a distance-based taxation system presented in this paper, where taxes on fuel and vehicle usage have been integrated. In the conclusion section we take a more global perspective, and we evaluate applicability of the presented taxation system for different countries.

1 Introduction

The political objectives to mitigate external costs of private car use and continuously advancing information technology have increased interest in alternative means to change current car taxation based on ownership and fuel consumption towards distance based taxation enabling tax level variations based on driving location and time of day. Tracking private cars using satellite positioning is already a technologically feasible option for focusing taxes to vehicle usage. However, the implementation of a taxation system based on satellite tracking most likely faces many technical challenges and related considerable costs. Reporting the movements of all vehicles on the road requires data transfer capacity and monitoring of proper operation of the equipment installed in the vehicles. Moreover, the use of driving routes as a basis for taxation requires a large register and computing capacity.

In Finland, the ministry of transportation commissioned a working group to study alternatives for road pricing in the long term. The final report of the working group titled “Fair and intelligent transport” was published at the end of 2013, presenting alternatives for the implementation of a kilometer based taxation policy projected on a future scenario set to year 2025 (LVM37/2013). The working group published also several reports which considered impacts, technical and juridical issues. One of the reports, titled “National km-tax for Passenger Cars Cost Estimation” describes technical details and cost structure for the implementation of alternative km based taxation systems (LVM39/2013). We use figures presented in these reports as a basis for comparison and evaluation of the integrated fuel and car use taxation system presented in this article.

The car and fuel taxation has had a significant fiscal role in Finland forming approximately 15 percent of total tax revenues. In the considered taxation systems and scenarios of this paper we assume that this fiscal objective remains as was assumed also in the above mentioned reports of the transport ministry of Finland.

The main idea in the integrated taxation system proposed in this document is that all the taxes of car use are included in the fuel price. The highest price of fuel is charged for cars driving only on urban areas during peak hours. Thus, the fuel price includes both the traditional fuel taxes and kilometer based taxes which are varied with geographical location and time, allowing tax returns for vehicles used outside peak hours and within less populated rural areas with weak public transportation connections.

The rest of the paper is structured as follows: In Section 2 we present the alternative taxation systems. In Section 3 we consider the main concerns related to the previously proposed systems. In section 4 we compare the costs of the taxation systems. In section 5 we consider implications of the taxation systems of tax revenues and external costs. Finally, in Section 6 the conclusions are drawn.

2 Alternative vehicle taxation systems

2.1 The current taxation system

The current taxation of private cars in Finland is based on three main taxes:1) fuel tax, 2) car tax, and 3) vehicle tax. In addition, fuels and cars are taxed by value-added-tax similarly with most of the goods and services in Finland.

The fuel tax consists of the energy content tax, the carbon dioxide tax and the supply security payment. In August 2014, the fuel tax was 0,965 €/liter for 95 octane gasoline and 0,776 €/liter for diesel. The car tax is paid only once when a car is registered (or taken in use) first time in Finland. The tax is calculated from the Finnish market price of the car (retail price), and the tax percent is based on CO2 emissions (or alternatively based on total mass and propelling force, if an information on emissions is not available). The vehicle tax is an annual tax, and it also varies with CO2 emissions. The vehicle tax consists of two parts, i.e., the basic tax, which is for all vehicles, and the propelling force tax, which applies only to vehicles using some other fuel than gasoline, primarily diesel.

2.2 Km-based taxation

The working group proposes a taxation system where fuel tax remains the same, but car tax and vehicle tax would be replaced by kilometer based taxes, which consist of three components based on driving zone, CO2 emissions and propelling force. Moreover, the working group presents three versions of the proposed taxation system: one with uniform kilometer tax and two with variable kilometer taxes for different geographical areas, i.e. higher kilometer taxes for more urban areas. Furthermore, they discuss about possibility for time-based component in kilometer tax (optional congestion charge/tax), but the possible effects of the time component on car use were not analyzed as the other tax components.

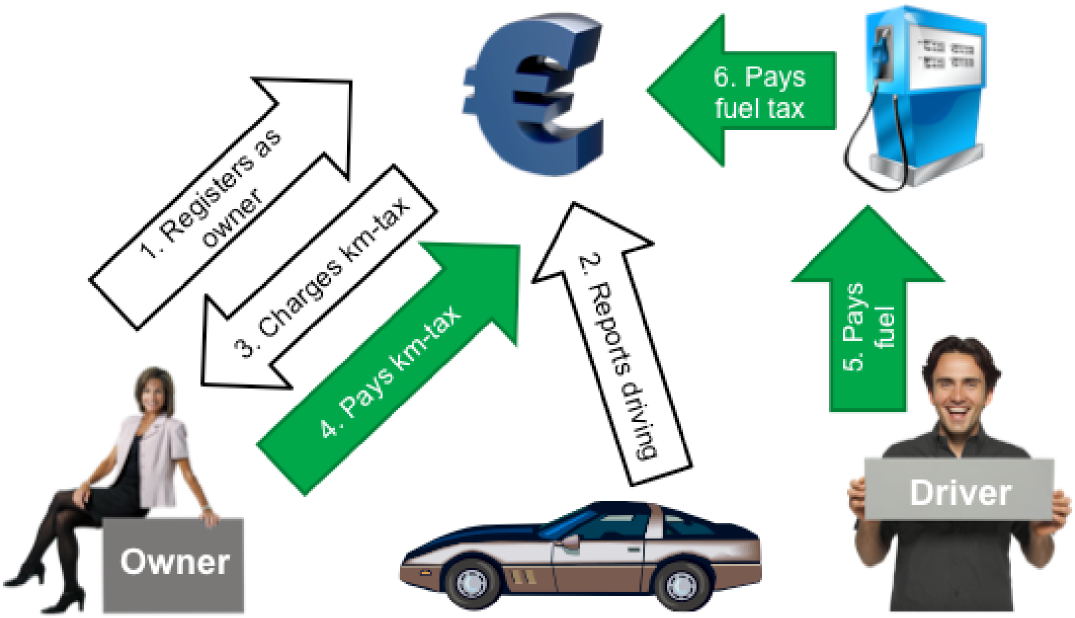

Figure 1. Transactions of the proposed km-tax

The transactions involved with the km-based taxation of vehicle use presented by the working group are illustrated in Figure 1:

1. The owner of the car is registered to tax officials as the responsible taxpayer. Vehicle-specific information may also be needed to fine-tune the km-price.
2. A device installed in the car reports data, which can be used to compute the distance driven, potentially including information about where and at what time the kilometers have been accumulated. Transmission takes places over cellular data. The data is proposed to be collected to a ”citizen account”, where tax officials have access limited to the data used as basis for the tax.
3. Tax officials charge the vehicle tax from the registered owner based on car profile and usage information.
4. The owner pays the tax.
5. The driver buys fuel to the car. The fuel includes fuel tax.
6. The fuel company pays the fuel tax to the state.

2.3 Fuel-integrated taxation system

We introduce an alternative model for location-based taxation of vehicle usage. Instead of collecting extra payments from driving in urban and congested areas, our model is based on a refund for the kilometers driven in low-traffic zones. The tax return can be processed with the next fuel purchase, which also allows data transfer to be carried out using local area networking technologies at the fuel station instead of stressing the cellular networks. This model also removes the incentive of tampering with the tracking device to prevent tracking. Fraud prevention needs to concentrate on not allowing the metering device to collect cheap kilometers onboard another vehicle.

Joining the system becomes cheaper to all drivers, so the required hardware purchase and installation can be voluntary. One way to drive down the cost of the equipment would be to use smartphones for location tracking. The only extra feature needed is to implement secure pairing with the car so that it can be clearly identified, in which vehicle the phone is travelling and that only one phone at a time per vehicle is registering the route.

The tax reduction can be processed as a discount from the price of the next tank of fuel for the car. This reduces extra payment processing for collecting the tax. Data transfer can be done wirelessly at the gas station, or the device of the car can have a smart card, which is fed into the card reader at the gas station in the same way that customer loyalty cards are used nowadays. If the kilometers are calculated by a smartphone, wireless LAN, bluetooth and NFC are all potential technologies for transferring the required information.

Figure 2: Transactions with the proposed fuel-integrated taxation system

The transactions associated with the proposed fuel-integrated tax are shown in Figure 2:

1. At fuel purchase time a device installed in the car reports all the parameters needed for calculating final tax. In addititin to distance information, car-related parameters (model, engine type, consumption data from on-board computer) may be included.
2. All refunds based on the reported driving information are processed by the gas station. The driver pays the remaining price of the new tank.
3. The fuel company jointly reports the transactions to tax officials and pays the final fuel tax.

No centralized register for vehicle locations is needed. Fuel distribution companies can jointly report the refunded taxes to officials, so there will be no new direct tax payments from car owners. The gas station infrastructure already exists and drivers of cars powered by liquid fuels have to stop for refueling. Therefore extra time costs to drivers due to the taxation system are minimal. The same taxation principles could also be applied for electric vehicles. The procedure could use similar information collection, but with additional payment transactions instead of refunds.

In order to calculate the tax reduction per fueling accurately, also the fuel consumption data of the vehicle could be saved. This can be obtained from the on-board computer of the car. Alternatively the reduction could be calculated relatively based on medium consumption, e.g. based on static parameters related to the car model.

3 Challenges of proposed distance based taxation systems

3.1 Technical challenges

No nation-wide system for collecting distance-based taxes from private cars was deployed in any country by 2013 (LVM37/2013). A number of technical challenges need to addressed, before the system can be taken into use.

The on-board units (OBU) used to calculate the parameters used as basis for tax calculation need to be reliable and tamper-proof. There may also be a need for e.g. the police to remotely observe, whether an OBU is installed and operational. The related technical requirements depend on whether the correct operation of the OBU results in costs (km-based) or savings (fuel-integrated) to the driver:

- **Cost:** The incentive to remove or incapacitate the device is to avoid paying tax. Preventing easy removal of the device is contradictory with the requirement for easy and cost-efficient installation and replacement, which are needed for country-wide deployment. The device also has to be resistant towards deletion of buffered data, radio disturbance, disconnection from car electricity and other means, by which an individual driver could try to avoid paying taxes. Since it is unlikely that all possibilities to incapacitate or remove the device could be covered, heavy surveillance by the police is needed. This is especially difficult and inefficient in rural areas.
- **Savings:** Accumulating more kilometers especially outside metropolitan areas result in greater savings for the driver. There could be motivation to load multiple OBUs into one car to accumulate cheap kilometers in rural areas. This should be prevented by coupling the OBU with the car so that only one OBU per car can be active. In case a mobile phone is used as OBU the coupling could be done with a certificate exchange using a suitable radio technology such as Bluetooth.

The technical challenges involved with a “hostile” device installed in the end-user’s vehicle are significantly greater than in the case of a device, which helps to incur savings. Coupling of electronics with a certain car has been used to prevent theft of in-vehicle audio equipment for a long time.

The second technically challenging step involves the transmission of the accumulated mileage data. The general assumption tends to be that data is transmitted over cellular networks, but (LVM13/2013) presents no calculation over the incurred load. It is also unclear, which part of the operational cost incorporates the payment to cellular operators.

The amount of reports can be calculated from the number of cars and the required reporting frequency:

<Number of cars> x <Reports per month per car> = <Reports per month>

Each report involves an overhead for authentication and security of the transmission plus the amount of payload transferred. The quantity of data transferred per report depends on the data reported:

- Total km per reporting period is very compact and independent of the length of the period.
- Zone- and time-based total km reporting is also independent of the length of the reporting period. The zone- and time-limit configuration would have to be available in the OBU and reconfigurable over the air.
- If zone- and / or time-information is required, but the configuration is not downloaded to the OBU, the timestamped locations of the car need to be reported. Location sampling should be based on the distance travelled. The size of a single report varies depending on reporting frequency, but the number of locations reported for a given time period would only depend on the distance travelled.

In the case of reporting total kilometers, the amount of data transferred is calculated as follows:

<Number of reports> x
(<Overhead> + <Nr of variants> x <Size of one reading>)
= <Amount of data transferred>

For location reporting the formula is modified as:

<Number of reports> x <Overhead> +
<Size of one reading> * <Nr of kilometers> * <Nr of reports per km>
= <Amount of data transferred>

Using the following assumptions from Finland:

- Amount of cars: 3.5 million
- Total annual kilometers driven: 50393.94 million (LVM37/2013 forecast for 2025)
- Authentication and reporting overhead: 1 kbyte per report
- One km-reading: 40 bytes
- One GPS location: 40 bytes

- Location reporting density: 1 location per kilometer driven
- In case of hourly reporting the car is assumed to be used during four hours per day on the average

Data transmission for three sample cases is calculated with results shown in Table 1. Estimated number of reports and amount of data transmission in Finland per month. The amount of data transferred depends fully on the encoding, compression and transmission protocols employed, so the figures should only be seen as indicative for one possible method of transmission. Reporting is needed only when the car has been used. Therefore, as the reporting density increases, there would be an increasing need to take into account that not all cars are used every day and every hour, or on all zone and time variants. In the table it is assumed that all cars are used every day on all zone and time variants up to the daily reporting level. For hourly reporting it is assumed that on the average cars would be used during 4 hours per day, but they would still accumulate kilometers on all zone and time variants during each of those four hours.

The main observation from Table 1 is that even though hundreds of gigabytes per month is a significant amount of data, it would not represent significant challenges to cellular 3G and 4G systems in 2025. This is because the necessary amounts of data transmission per car are relatively small compared to e.g. video streaming. Heavy users are already in 2014 using cellular data in the excess of a gigabyte per month per user. Still, 3.5 million cellular subscriptions transmitting up to hundreds of gigabytes per month cannot be entirely neglected as a cost.

	Million reports per month	Data transferred [Gigabytes per month]		
		Total km	Total km for 20 zone + time variants	Locations
Monthly reporting	3.5	3.5	5.9	159.8
Weekly reporting	15.17	15.0	25.8	170.9
Daily reporting	106.46	105.5	180.8	258.0
Hourly [4 hrs per day] reporting	425.83	422.0	723.4	562.5

Table 1. Estimated number of reports and amount of data transmission in Finland per month

The third large technical challenge is the collection of the charging data, billing individual drivers and handling any disagreements regarding charging. In (LVM37/2013) the cost of distance-based taxation is estimated at 126-133 million EUR, which would be 5.8-6.7% of the incurred tax revenue. The taxation cost share of the fuel tax income is currently 0.01%. Possibility to couple distance-based tax charging with fuel tax would greatly improve the efficiency, although some costs related to storing of distance-based charging data and handling disagreements would still be incurred.

The fourth challenge, if taxation is tied to ownership rather than vehicle use, is to direct the cost to the user. Car rental companies will develop billing methods to handle the charges, but e.g. within extended families ("borrowing mother's car" has been stated as an example) this will require extra transactions to compensate the owner. If the distance-based tax charge is embedded in fuel charge transactions, it is very straightforward for someone else than the owner to compensate both the fuel and the taxes.

Finally, coupling the OBU with a charging account of the owner means that changes either in the account, or even the OBU hardware (in case of another service provider) may be needed. In Finland there are about 600,000 car ownership changes per year.

3.2 Legal challenges – data protection

In Finland data protection (also called privacy) has perhaps been the most debated legal issue in relation to the proposed satellite based car taxation system. Therefore we will discuss in this section only the data protection aspect of the work group's proposition (LVM37/2013) and compare it to our alternative taxation model.

The importance of data protection is recognized also in the report of the work group. The report emphasizes that in the planning phase it should be carefully evaluated, which one of the alternative solutions would be least privacy invasive. Possession of traffic data and ability to process (e.g. collect, combine or transfer) data are relevant factors when evaluating data protection. The report also emphasizes utilization of the ”privacy by design” principle throughout the whole engineering process.

The report points out that the tax authority does not really need to hold the traffic data but the calculation (or the amount) of the tax based on traffic data. Thus data subjects would not have to worry about the misuse of their traffic data by the tax authority (e.g. making it available to other entities without permission).

The report states that instead of an authority administrated register traffic data could be in the possession of each data subject. The report suggests that a so called ”Citizen's Account” (https://asiointitili.suomi.fi/) is an example of such a register. Citizen's account is a web site where people can receive official decisions concerning the services that are linked to citizen's account instead of by post. Some of the authorities also receive messages via Citizen's account.

The problem with the citizen's account approach is that it is not really in the possession of the citizen. The data is not recorded on the citizen's device or on an account administrated by the citizen. The citizen may read the traffic data recorded, but she is not able to prevent the administrator e.g. from transferring the data to unwanted third parties. Neither can she impact how accurate or real time data is recorded. Therefore the citizen's account approach does not alone resolve the privacy challenge.

The legal work group points out that neither real-time nor detailed location information are necessary for taxation purposes (LVM41/2013). Also Finland's Data Protection ombudsman Reijo Aarnio has in many public events emphasized the importance of the practice of recording only the necessary information for taxation. Intelligent location and context aware mobile services need real time and accurate traffic information. Therefore traffic information collected for car taxation purposes might not be an ideal basis for commercial mobile services.

In our alternative taxation system (the fuel-integrated taxation) traffic data would be in the possession of car drivers. Car drivers could even decide whether to record traffic data for getting discounts from taxes. They would not need to worry about the sensitive nature of the data and about the threat of unwanted secondary uses. On the contrary, they would have an incentive to record real time and accurate traffic information for getting better commercial services. To sum up, in relation to data protection, our alternative tax model has many advantages compared to the work group's proposition.

4 Cost comparison of taxation systems

In this section we present a cost comparison between the three taxation systems, which were introduced in section 2, i.e., the current taxation system, the kilometer based taxation system and the fuel-integrated taxation system. The working group presented a detailed cost estimate for the kilometer based taxation system, which provides a useful starting point for the cost comparison.

The working group presents cost estimates for three versions of kilometer based taxation system. The first version enables location based kilometer taxation. The second version enables location based kilometer taxation, but it also enables commercial services for the car users (multiservice-model). The third version enables only uniform kilometer taxation without localization of vehicles. We consider only the first of these versions in our cost comparison, because it fulfills basically the same functional requirements as the integrated taxation system.

The estimated investment cost of kilometer based taxation system is 462.5 million euros where the share of equipments installed in the vehicles is 330 million euros, and the rest 132.5 M € is for many cost items like monitoring equipment (31 M €), "plug & play equipment" for foreign vehicles (50 M €), IT-back office (25 M €) and other smaller cost items.

The estimated annual operating cost of kilometer based taxation system is 133 million euros consisting of several cost items like administration, tax collection costs and personnel costs of monitoring, and the costs are significantly higher than the operating costs of the current taxation system, which are only 16.58 million euros per year. The efficiency rate presented in Table 3 is calculated by dividing the tax revenue with the operating costs of the tax system, and it shows that the current system is the most efficient of the compared taxation systems. This comparison ignores impacts on external cost, which are considered further in section 5.

The estimation of cost differences between two technologically advanced taxation systems, which are not yet implemented anywhere in the world, is a challenging task. However, we have perceived and analyzed (in section 2) many technological differences between the systems, and based on these differences we present cautious cost estimates for the fuel-integrated taxation system. The cost estimates of Km-based taxation system are from (LVM13/2013). The complete list of cost estimates with related reasoning in parenthesis is presented in Table 2.

Annual operating costs	Current taxation system	Km-based taxation system	Fuel-integrated taxation system
fuel tax	0.58	0.58	0.58
car tax	5	0	0
vehicle tax	11	0	0
km-based system:			
administration	0	9	5 (payments concentrated via fuel companies, less transactions for tax administration)
OBU	0	10	8 (less strict security requirements)
tax collection, domestic	0	53	25 (less transactions for administration, no additional charging)
Tax processing, fuel companies	0	0	5
tax collection, foreign	0	20	10 (less transactions, no additional charging, option to pay full tax instead of renting OBU)
support and maintenance	0	1	1
monitoring, personnel and equipment	0	26	15 (less effort needed for monitoring OBU usage)
other	0	1	1
EETS operator payment	0	3	3
depreciation	0	12	10
Total operating costs	**16.58**	**135.58**	**83.58**
efficiency rate (%)	0.3	2.5	1.6
Investment cost	0	462.5	400 (less technical requirements, less monitoring and transactions)

Table 2. Cost estimates of the taxation systems (million €). The estimates of Km-based system are from (LVM13/2013). The estimates of Fuel-integrated system are based on technical differences compared to Km-based system, and the main differences affecting to the cost estimates are reported in the parenthesis after the estimates.

5 Impacts

5.1 Impacts on tax revenues

To illustrate alternative taxation systems we consider one of the user scenarios presented by the working group (LVM37/2013), where a car consuming 6.5 l gasoline per 100 km and having CO2 emissions of 152 g per km had kilometer tax of 3.057 cents per km. If we use the same value for kilometer tax in the fuel-integrated taxation, then the total price of gasoline would be 2.07 € per liter, where the price with current fuel tax is 1.6 € and 0.47 € increase in price is due to the kilometer tax. The working group also considers uniform kilometer tax of 3.3 cents per km (LVM37/2013), and in that case the total price of gasoline would be 2.10 € per liter in the fuel-integrated taxation.

The starting point for the analysis of tax revenues from the alternative tax components is the scenario for year 2025, where the total tax revenue from car use and fuel tax is assumed to be 5.35 billion € corresponding to approximately 15 percent of the annual total tax revenues of Finland. The scenario and related impact evaluation are based on traffic predictions and simulations conducted by the traffic models developed by the Finnish Transport Agency (LVM38/2013).

Table 3 describes the tax components of the alternative taxation systems and presents the tax revenue estimates for all tax components for year 2025. As can be seen from Table 3, the car tax and vehicle tax have been removed from the Km-based taxation and the Fuel-integrated taxation. These two taxes are replaced by km based tax in the second tax system, and by combination of increased fuel tax and negative km based tax in the third tax system respectively. Thus, in the Fuel-integrated taxation the total fuel tax revenues with maximum price per liter would be 6922 million €, but the tax reductions based on driven kilometers outside urban and congested areas leads to decrease of 1630 million € in tax revenues.

Tax components	1.Current taxation system	2. Km-based taxation system, (uniform)	3. Fuel-integrated taxation system
Car tax	1000	0	0
Vehicle tax	826	0	0
Propelling force tax for trucks	50	50	50
Fuel tax, petrol	1311	3289	6922 (=3289+2003+1630)
Fuel tax, diesel	1260		
VAT	905		
Km based tax		2003	-1630 (reduced taxes based on driven location and time)
sum	5352	5342	5342

Table 3. Alternative taxation systems and estimated tax revenues (million €) for year 2025.

5.2 External costs

The working group's report (LVM37/2013) presents a prediction that the number of car trips in 2025 would be 3500 million trips without any changes in taxation, and the km-based taxation would reduce 30 million car trips, which would be travelled by public transportation and airplanes. The report presents that the reduction in car trips brings 14.7 million € external cost savings from reduced CO_2 emissions and 166 million € savings from reduced accidents. Possible impacts on congestion and travel times are mentioned, but estimates on congestion cost and costs of increased use of other transport modes are not presented in the report.

The congestion cost in Finland is estimated to be between 0.07 – 0.10 $ (0.054 – 0.077 €) per car kilometer (IMF, 2014). We used an average of the range (0.0655 € per car kilometer) to estimate congestion cost savings from reduced car trips due to the use of the km-based taxation or the fuel-integrated taxation, which resulted in 162 million € savings in congestion costs. This estimate is very simple and it is based only on the scenario where driven kilometers have uniform tax. The higher congestion cost saving could be achieved by time-based variation in taxation.

6 Conclusions

We have reviewed the results of the working group commissioned by the Finnish ministry of transport to study alternatives for car use taxation in the long term. One of the main conclusions of the working group was that Finland should proceed towards distance-based taxation by experimenting and testing required technologies.

We have also described an alternative approach denoted "fuel-integrated taxation system", likewise enabling taxation based on travelled distance, location and time, but based on a fuel tax refund instead of an extra charge. We have explained that the fuel integrated taxation system has many technical advantages, which seem to improve cost efficiency and data protection compared to the basic km-based taxation system. Thus, the fuel-integrated taxation system should be taken as a potential alternative when considering and developing new transport taxation systems in Finland. Variants of the system could be applicable for other countries as well.

The main challenges of fuel-integrated taxation are the treatment of electric cars and potentially differing policies on country borders. The share of electric cars is likely to become significant in the future and even though electric cars don't cause local emissions, they contribute to congestion and should be subject to same congestion fees as cars using liquid fuels. As electricity cannot be ear-marked for "cars only", no car-specific electricity tax can be charged and no refund mechanism is possible. The primary approach for electric cars would then be paying tax instead of a refund. If the fuel prices across country borders are very different, extra traffic will be caused by fuel purchase trips. Therefore fuel-integrated taxation would work best, when applied to a larger area than one country.

In developed countries congestion costs are the most important external costs due to the high value of travel time. Therefore distance based taxation with a time component would be beneficial especially for developed countries which have not implemented congestion charges.

In developing countries the relatively high investment cost and costs for car owners might be a great challenge. However, a major advantage of the integrated taxation system is that it enables voluntary use of car-installed on-board units (OBU). Drivers who almost always drive within urban areas during peak hours don't necessarily need to collect any driving information, because they would not receive tax reductions anyway. Thus, the system could save a part of the drivers from buying an OBU, but it could still change decisions on transport mode, route and time of day for trips from rural areas to the urban areas.

Finally, if this kind of a system is taken into use, a European standard would be beneficial so that the same OBU would work across country borders and there would not be sharp variations in fuel prices. The same tax reduction should be available for both locals and visitors.

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