Towards a kilometre charge in road transport. An investigation for the Netherlands

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Abstract

This study discusses the potential effects of a kilometre charge in the Netherlands on pollution and travel demand. It also discusses the organisational and technical structure which is required to introduce a well-functioning system of charging passenger cars for each kilometre driven.

It appears that the introduction of an advanced kilometre charge can lead to a reduction of environmental pollution caused by car traffic (depending on the kind) with 20% till 70%. When the introduction of a kilometre charge is combined with a reduction of taxes on car ownership, the average costs of car use will not rise.

keywords: environment, transport, taxation, budgetary neutrality, car use, car ownership

1. Introduction

The pricing of road use is characterised by several imperfections. Issues of environmental pollution, noise, accidents and congestion are usually not addressed in a direct way, but only indirectly. This yields a system that has mainly a second best character. For example, excise duties on fuel are a major way in many countries to address the external costs of transport. Such taxes are adequate when the only objective is to reduce CO_2 emissions, but they are rather crude when one wants to address some of the other externalities. An additional problem with fuel taxes is that tax differences in border regions may have adverse effects. Another example of a second best price instrument is the imposition of tolls on interurban highways. Since these tolls can usually be avoided by taking other types of roads, this may lead to adverse effects on traffic safety and environmental quality. Cordon charges in congested areas are another example of a second best instrument. Since these charges are not distance dependent, they address the contribution of cars to congestion in a rather crude way. With the development of ICT, the technological possibilities for more refined charging systems have improved. For example, in Switzerland a km charge has become effective for trucks after the first of January 2001. This study addresses the possibility to introduce a kilometre charge in passenger transport.

This study is focused on car traffic in the Netherlands. The current tax system consists of three components: a fixed charge on new cars (the so-called BPM, 45% of the net price minus a deduction fee depending on the type of fuel), an annual charge for every car owner (MRB, depending on the weight of the vehicle and to be paid each quarter) and a fuel tax. The only variable component, depending on the use of the vehicle, is the fuel tax. The share of the fuel tax in car related taxes is about 45%. This tax system does affect the level of pollution because heavier and more expensive cars are higher taxed and the amount of fuel used is taxed. However, the relationship is often weak, indirect and subject to side-effects. Besides, the system hardly affects safety, congestion and noise. From these perspectives it is desirable to make the tax system more variable. Politicians are also more and more interested in variabilisation of the transport costs. For example, charging traffic based on the full costs caused is one of the major issues addressed by the European Commission (see the paper on fair payment for infrastructure use, EC, 1998). Also in the Netherlands, the government is interested in reinforcing the relationship between intensity of use and payment (see Ministry of VROM, EZ, LNV and VenW, 1999).

The possibilities to charge traffic in an efficient way have been limited in the past. It seems that this situation is changing because of new technological possibilities with acceptable costs. Governments can use various options. A well-known example to address congestion is electronic road pricing in Singapore where a charge is levied for the use of the road on a certain time and place. Another possibility is an electronic kilometre-charge. A kilometre charge implies the payment of a certain charge for each kilometre by the vehicle user. This system offers advanced possibilities to charge costs to those who cause them. The kilometre charge makes the entire variabilisation of car-costs possible, which is not the case in the current regime. Car drivers who travel many kilometres will obviously pay more. This system will remove the current situation in the Netherlands where car drivers making many kilometres pay low fuel prices (due to lower taxes on LPG and diesel). Thirdly, this advanced kilometre charge makes it possible to differentiate the charge according to energy-use, emissions, noise, road safety, driving style and congestion. In the current system of charges and taxes it is not possible to let drivers pay based on these characteristics.

It is possible to implement this system of kilometre charging in various ways. This depends on the aim of implementation and type of variabilisation. It is for example possible to replace all fixed components of the current tax system (MRB and BPM). However, also other alternatives can be regarded as a suitable option. The aim of this paper is to consider the (technical) feasibility of a system of kilometre charging in the Netherlands. Practical and organisational aspects of the system will be outlined. In addition certain implementation alternatives and their effects on car transport and the environment will be discussed.

This paper is organised as follows. We start with a discussion on principles for pricing transport (section 2). Section 3 contains a discussion of the structure of marginal costs of road transport. Technological aspects of a kilometre charge are discussed in section 4. A review on the effects of a kilometre charge is presented in section 5. In section 6 a more detailed account is given of the effects of four alternative ways to introduce a kilometre charge. Implementation issues are discussed in section 7. Section 8 concludes.

2. Principles for pricing transport

Several principles are used in the discussions on the pricing of transport:

-efficiency

-equity 1: balance between what people get and what they pay;

-equity 2: balance between what people need and what they can afford.

The *efficiency principle* states that the optimal level of transport is achieved when the marginal cost of an extra kilometre of transport is equal to the marginal benefit. Since the marginal benefits of transport tend to decrease with the distance travelled, and marginal costs are constant or increasing, there will be a point where marginal costs and benefits converge. Reason for concern is that, due to the external costs mentioned above, travellers are not incurred with the appropriate level of costs: for example, they tend to ignore noise problems produced by the aircraft in which they travel. This situation leads to over-consumption; a charge for the externality to correct for this would increase the marginal costs as experienced by the traveller, implying a decrease in the distance travelled.

The *equity 1* principle stipulates that there should be a balance between what people pay and what they receive. This principle is often used for road transport. There is a general feeling in many countries that road users pay more than they get in terms of quality of infrastructure available to them, but for public transport services the reverse often holds: the existence of subsidies implies that public transport users get more than they pay.

The *equity 2* principle is used for specific groups, such as handicapped persons, elderly people and persons living in isolated areas (peripheral rural areas, islands, etc.). The discussion in this context is on the extent to which the public sector has a task to correct for the gap between transport needs and the costs of producing the services, and, if such a task has indeed been identified, how to reduce this gap. The problem can be resolved by a lump-sum income transfer, a dedicated transfer of income (e.g., via vouchers used for transport), subsidies on transport activities conducted by the private sector, or the organisation of transport by the public sector itself. The reasons for the large gap between what persons in these groups can afford to pay and what the transport services cost emerge from two entirely different sources. The first factor is that the income of the groups in question is usually low (most handicapped people depend on social welfare payments; isolated areas may well have low average income levels). The second factor pertains to the costs of providing the services: elderly and handicapped persons may need specially adapted carriages and services with high costs. People living in isolated areas encounter high costs because of the lack of opportunities to exploit economies of scale.

We will not enter into discussion of the third pricing principle here because it obviously refers to rather specific market segments. Insofar as the first two principles are concerned it is important that the efficiency principle is strongly connected to the notion of *marginal costs*, whereas the equity 1 concept corresponds to *average costs.* Another difference between the two principles is that efficiency considers all costs, whereas equity 1 usually focuses on the position of the public sector in the distribution of monetary flows into and out of the public budget.

The importance of the notion of marginal costs of transport can be illustrated by comparing them with the well-known lists of the total costs of transport (see Quinet, 1994). For example, the total costs of transport can be estimated by including figures concerning accidents, various types of pollution, congestion, etc. Especially the costs related to accidents may appear to be rather high in many cases; the problem with such figures is usually that they ignore the difference between average and marginal costs, and that they are not explicit on the question to what extent they are external. The first point (marginal versus average) is especially clear if we consider the costs of delays due to congestion. The very nature of congestion implies that the marginal costs may be much higher than the average costs (see also Small, 1992 and CE, 1999). Within the category of accidents there may also be a substantial gap between average and marginal costs. An extra car km may lead to more congestion and hence to lower speeds, thus implying lower risks (cf. Blauwens *et al.*, 1995; Persson and Odegaard, 1995; and Shefer and Rietveld, 1997).

The second point is that the failure to distinguish between external and internal costs may lead to a distorted view. For example, it is estimated that most of the accident costs of transport in the Netherlands apply to costs of damage and costs of health care, which are already paid by the causal agent of the accidents (SER, 1999). These costs are of course still important as determinants of transport volumes, but they do not deserve special attention in transport pricing policies.

3. The structure of marginal costs

3.1 External costs of transport

In table 1 we compare some external effects of transport with a number of features of drivers, vehicles and infrastructure. That the levels of the external effects usually depend on each of these factors is noteworthy. For example, noise nuisance imposed on citizens in the area depends on number of kilometres driven, road type (location of nearby dwellings), car type, time of day (during the night nuisance may be higher), and driving habits, such as speed and acceleration behaviour. A similar result is found for most of the other external effects of transport. This table leads us to an obvious conclusion: it is not meaningful to speak of one uniform level of external costs of car transport, because the actual level may vary strongly according to a large number of situational circumstances.

Table 1. Determinants of the external costs of transport

	number of kms driven	road type	car type (technology)	time of day	driving habits
Noise	x	x	x	x	x
Accidents	x	x	x	x	x
Pollution	x	x	x	x	x
Congestion	x	x		x	

Source: Rietveld (2001)

3.2 Actual pricing of mobility

It is interesting to compare the notion about the dependence of actual external costs on a large number of situational circumstances with the actual pricing of mobility in the Netherlands. In table 2 we compare the Netherlands with two other countries (Switzerland and Japan) and observe a substantial part of total tax payments allotted: they are paid once when a new car is purchased and regularly when one owns a car, but these payments do not depend on actual vehicle use.

Table 2. Taxation of car transport in various countries according to source (%), 1997.

	new vehicles	vehicle ownership	vehicle use (fuel)
The Netherlands	31	24	45
Switzerland	10	19	67
Japan	11	18	71

Source: NVWB (1997)

When we draw a parallel between the Dutch situation of taxation and the various factors outlined in table 1, we see that fewer than half of the total tax receipts correspond to the use of cars. A strong differentiation takes place with regard to the fuel inputs: taxes on diesel and LPG are relatively low per litre, while the taxes on owning cars that use these fuels are relatively high. Taxes also vary according to car type: owners of heavy cars pay higher taxes. No differentiation takes place according to type of road (toll roads are almost non-existent in the Netherlands), time of day (no use of congestion pricing) and according to driver's features (there may be some differentiation in insurance premiums, but this is handled by the insurance companies, not the public sector).

We conclude that the present structure of Dutch car taxes is mainly aiming at influencing the choice of car technology, and much less at the actual intensity of car use. The structure of the tax system in the Netherlands is only vaguely related to the differentiation in the external effects. Especially for the most rapidly developing problem of congestion, the tax system is not very helpful. Part of the problem is that the fixed part in the total taxes is rather high. This has led to the issue of variabilisation of transport taxes.

3.3 Variabilisation

Variabilisation may be described as a budgetary neutral shift of fixed to variable taxes. Budgetary neutrality means that the total tax receipts remain constant. In the case of inelastic demand for transport, this concept can be applied in a straightforward way, since when the volume of transport is given, one can easily compute the consequences of a reduction in the fixed costs for the increase in variable costs. However, when demand is elastic and (car use) elasticity for variable costs is higher than for fixed costs, such an increase in variable costs would lead to a decrease in transport volumes. Thus, in order to keep the total tax receipts constant, the increase in variable costs should be larger depending on the difference between elasticity for variable costs and for fixed costs.

Budgetary neutral tax reforms are expected to be better received in the political arena compared with a simple increase in taxes. Budgetary neutrality is a simple example of a policy package approach with a mixture of attractive and unattractive elements. There is clear evidence that in the field of road transport drivers prefer schemes of variabilisation where the additional receipts flow back to the group paying the money, compared to schemes where the additional receipts are used for purposes where other people may also benefit. Examples of the latter are a general reduction of the income tax, or investments in public transport infrastructure (Verhoef *et al.*, 1997). The obvious result of variabilisation is that travellers who travel long distances per year are confronted with higher costs. Travellers with distances below the break-even point would benefit from budgetary neutral tax reforms. A few obvious candidates for practical implementation of variabilisation that have received attention in the Netherlands are an increase in:

- *Fuel tax*
- *Parking*
- *Tradable permits*
- *Congestion pricing and tolls*
- *km charge*

In the present situation the fuel tax is the main instrument to achieve variabilisation in transport. Its large advantage is that it is easy to implement. One of its shortcomings is that it focuses on CO_2 emissions, the other pollutants remaining unaffected. In addition, it leads to cross border fuelling practices when fuel taxes differ too much from those in neighbour countries. Parking charges by definition address the non-use of vehicles and hence are not an appropriate instrument to deal with externalities of vehicle use. Tradable mobility permits have been proposed in some countries, but there have not been serious efforts to implement them thus far. Congestion pricing is an instrument that focuses on one particular negative externality in transport, so that it is only levied in congested situations. A kilometre charge is a much more general instrument in this respect, since it addresses all kilometres driven and all externalities. In the next section we discuss a kilometre charge in more detail.

3.4 The kilometre charge

The kilometre charge can be used in a generic way to charge drivers for the use of the infrastructure. The following table (Table 3) gives a qualitative overview of the extent to which various non-private costs of road traffic depend on the most relevant behavioural dimensions. A three-point scale indicates the possible dependency. From this the following dimensions show up: car ownership, car use (driven kms and trips), car technology (weight, cleanliness motor), time of driving, place of driving (area and more precisely route), driving style and finally spatial behaviour. Except for the last dimension, these aspects form a good starting point for differentiation of the kilometre charge. In this way it is in principal possible to include all external costs into the price for mobility. One might argue that such a differentiated kilometre charge can be interpreted as a generalisation of road pricing. It can also be considered as a generalised version of tolling. The kilometre charge would enable one to avoid the construction of toll booths. Compared with the fuel tax, an attractive feature of the kilometre charge is that it is less sensitive to the border problem than a fuel tax would be.

Table 3: Dependency from various external costs of road traffic of the most relevant behavioural dimensions

	Car ownership	**Car use**		**Car techn.**	**Time**	**Place**		**Driving style**	**Spatial behaviour (derived effects)**	
		Vkm's	***# Trips***			***Area***	***Route***		***Living......***	***Work/other***
Congestion	–	+	–	–	++	++	++	++	++	++
Flow	–	+	++	–	++	++	++	–	++	++
Bottleneck										
Emissions	–	++	++	++	–	+	–	+	++	+
CO	–	++	++	++	+	++	–	+	++	+
VOC's	–	++	+	++	+	+	–	+	++	+
NO_X	–	++	++	++	–	++	–	+	++	+
Particul's	–	++	–	++	–	–	–	+	++	+
SO_2	–	++	–	++	–	–	–	+	++	+
CO_2										
Noise	–	+	–	++	+	++	+	++	++	+
Safety	–	+	–	+	+	+	+	++	+	+
Wear end tear of road	–	++	–	++	–	+	+	–	++	+
Parking	++	–	+	–	+	++	–	–	++	++

– no strong or direct connection

\+ moderate connection

++ strong or direct connection

Source: Verhoef (1999), adapted

4. Technology and organisation of a kilometre charge

4.1 Introduction

It is clear that a system of a kilometre charge has to fulfil certain requirements. The system should not only be able to deal with the various differentiation aspects (e.g. measure driving style, emissions and compose the charge based on this data) but also with fraud and privacy matters. The system should also be designed in such a way that it is in accordance with existing (European) rules. Here we will shortly discuss the proposed system for the Netherlands. For more details we refer to Peeters et al., 2000.

The proposed system for implementing a kilometre charge consists of three elements: in-car equipment (on board unit, OBU), out of car equipment (DSRC) and an organisational institute (the so-called Kilometre Charge Service). This latter will regulate payments, as well as inspection, control, maintenance and fitting of the equipment into the cars. In relation to privacy matters a decentral in-car system has been chosen. This puts a great burden on the OBU, but it prevents central institutions from gathering and storing numerous data. This latter would increase the risk of improper use of these data with privacy problems as a result.

4.2 In-car equipment

The OBU is derived from an existing device, the TRIPON of the Swiss manufacturer Fela. The TRIPON has been installed during 2000 on all Swiss heavy trucks enabling all Swiss truck drivers to pay a simple form of a kilometre charge per January 1, 2001. This OBU registers the kilometres and writes the charge on the smartcard (both shown on a display). The TRIPON is relatively expensive but it offers good reliability, accuracy and it is fraud resistant (see for more detailed requirements and functions of the OBU Peeters et al., 2000).

The TRIPON uses three ways to reliably measure the place, distance and speed of the car: GPS, accelerometer and electronic odometer. This triple measuring is common in advanced car-navigation systems. If results are continuously conflicting the OBU will be set to an error-mode, displayed and blinking an error light. From that time on the OBU will register all (false and proper) data to its memory.

4.3 Road site equipment

The DSRC-portals serve to prevent fraud. It is estimated that around 200 DSRC portals are needed, plus a number of mobile stations. This equipment enables the OBU to exchange data at each passage in order to establish a direct check of the proper functioning and reading of place, time and (possibly) speed. When the check demonstrates that something is wrong, the data of the car will be sent to a central computer. There, the data will be checked upon tax evasion and the car owner will be given notice.

4.4 Organisation

The task of the ‘Kilometre charge Service’ consists of the registration of the vehicles and the OBU, programming of the vehicle data in the OBU, collecting the payments (via the prepaid smartcard), managing the system, certification of garage-keepers (which are allowed to install the OBU), maintenance and fine-tuning. Besides, this organisation takes care that the system meets European regulations. The level of charges will be established by political decision-making.

4.5 Phasing

It is interesting to obtain insight into the time-span which seems necessary to introduce a system of a kilometre charge based upon the above described features in the Netherlands. The following is a rather tentative schedule, but does seem feasible.

In a first phase several preparations are needed. This phase deals with submitting (new) legislation, composing technical specifications for the OBU, making a system of OBU-certified garage keepers and preparations of the DSRC-portals.

In a second phase the kilometre charge will be introduced for trucks, in conformity with the initiatives for Switzerland and Germany.

The third phase is needed in order to get OBU’s installed in all existing passenger cars involved. Given the large number of cars, this will take more than a year. Of course, during the period of transition, all new cars will be equipped with the OBU. Fiscal measures may be used to stimulate car drivers to early adopt an OBU during the transition period.

In a fourth phase all Dutch cars should participate in the system and the system can then be fully effective.

5. A review on the effects of a kilometre charge and variabilisation in the Netherlands

5.1 Introduction

Economic theory points out that people are using their cars as long as the marginal benefits of an extra car-kilometre are higher than the marginal costs of this kilometre. The marginal costs of an additional kilometre are equal to the variable costs. A car driver is to be expected to make a trade-off between the benefit of an extra kilometre and the variable costs. In the case of variabilisation these marginal costs will be increased while at the same time the fixed costs will be lowered or remain constant. There are various forms of variabilisation (see section 3). Raising the fuel price is one form, implementing a kilometre charge another. In both cases fixed taxes (e.g. MRB or BPM) will be reduced.

In the following we will shortly discuss the effects of variabilisation. Herewith, the empirical results from studies conducted in the Netherlands will be used to get insight into the expected extent and direction of the effects. Only a few studies have been carried out on this subject so the empirical material is rather limited. Two studies have been found which pay attention to the expected effects of a kilometre charging system. The effects on the following characteristics will be discussed: total number of cars, fuel-mix of the vehicles, environmental performance of vehicles, number of kilometres and the usage of public or non-motorised transport.

5.2. Total number of cars

The price of a new car is an important factor in determining the total size of the car fleet. In addition, the user costs of a car will play a role, but only modestly. Variabilisation means that the fixed costs will decrease, while the variable costs will show an upward movement. People without a car may decide to purchase one after the implementation of the measure, as cars become cheaper. Theoretically one may expect that variabilisation will lead to an increase in car ownership. However, the effect of this increase in ownership will probably not lead to a substantial growth of the number of car kilometres driven. The stimulating effect on car ownership is only to be expected in groups that are covering relatively few kilometres. Research suggests a treshold value of around 8000 kilometres (de Jong, 1989). The purchase of a car is mostly unattractive for people driving less kilometres. It is to be expected that this value will shift downwards, when variabilisation of the tax structure takes place. Besides, it should be noted that when car ownership of households increases, it often means the purchase of a second car. A part of the kilometres driven with this car were before driven by the first car so that the first car is used less. Thus, these extra cars will not lead to many extra kilometres.

Remarkable in this respect is the fact that results from former studies point at a *decrease* of car ownership as a consequence of variabilisation (implementing a kilometre charge, Muconsult, 1998). The increase in car ownership caused by lower prices of the cars is less than the decrease caused by higher variable costs. This would suggest that rather many people (driving many kilometres) are putting their car aside. Similar results are found in another study on an increase of the fuel price and decrease of some fixed costs (by using the FACTS model, Boose et al., 1996). Depending on the way of variabilisation, it appears that car ownership in 2020 is 2.5% till 4.4% lower compared with a scenario without variabilisation. However, a calculation with another model (the Scenarioverkenner of TNO-Inro) does predict a decrease of car ownership with 1.5% when the variable costs of car use will rise with 75%! Complete variabilisation of current taxes will lead to an 8% increase of car ownership following this model.

These rather indecisive results on the effects of changes in price structures on car ownership are confirmed by Bates (2000) who concludes, based on a review of the international literature that it has been difficult to introduce price terms in car ownership models. Since variability of prices is usually rather low, it appears difficult to estimate models being able to simulate the effects of changes in price structures on overall car ownership. It can be concluded that there are some contradictory results concerning car ownership following the above mentioned studies. We conjecture that effects on aggregated ownership are rather limited. However, more research in this field is strongly recommended.

5.3 Fuel-mix

In the Netherlands there are three main types of fuel used for passenger cars: petrol, diesel and LPG. The tax structure in terms of fixed and variable taxes is such that petrol cars are mainly used by drivers who drive less than 20,000 kilometres per year, whereas diesel and LPG are mainly used by drivers with a high annual kilometrage. Thus, whereas the share of petrol cars among all passenger cars is about 82%, its share in the annual kilometres is clearly lower: 67%. Variabilisation of the tax structure will obviously change these shares.

When for example only the fixed taxes disappear, cars using diesel and LPG will become more attractive because of the lower costs per driven kilometre. The kilometre charge can correct for this distortion by applying a higher charge to vehicles using these types of fuel. It may be clear that the way of variabilisation is decisive to the impact on the fuel-mix. The empirical studies did not provide insight on this subject.

5.4 Environmental performance

Depending on the differentiation in the implemented kilometre charge the composition of the car fleet can be influenced. The charge can (partly) be based upon the environmental performance (e.g. emissions) of a car. But also the system of fixed charges at the moment of purchase can influence this aspect. The price of a car can be based upon its relative or absolute environmental performance. More environment friendly cars will be purchased when the costs of environmentally unfriendly cars are increased and/or the costs of environmentally friendly cars are decreased. In section 6 this measure will be included in the discussed alternatives. Empirical evidence of changes in the total vehicle stock due to changing variable costs is scarce in literature. The study of Muconsult (1998) outlines that, depending on the way of variabilisation, a bigger car is more often abolished than an average or little car. These effects are stronger when the charge is higher or differentiated according to the weight of the car. In addition, this study shows that some car drivers will replace their car by a more fuel efficient one. Depending again on the way of variabilisation between 1.1% and 2.7% of the total vehicle stock will be replaced by a more fuel efficient type of car.

5.5 Number of kilometres

The total number of kilometres is mainly determined by the variable costs. Besides, a secondary effect can be expected from changes in car ownership. Modelling studies carried out towards the effects of a variablisation on the number of kilometres show considerable effects on the vehicle use. From the Muconsult (1998) study it appears that particularly high (14 ct/km) and differentiated kilometre charges (depending on the weight) can lead to a substantial decrease in car kilometres (between 19.6% and 17.1%). However, another study (Boose et al., 1996, see section 5.2) shows considerably lower results (between –0.4% and –6.5%). But this study is not based on the implementation of a kilometre charge: it models increases in fuel prices. Finally, a study by HCG (2000) reports a decrease in kilometres compared with a reference scenario for 2010. It appears that a decrease of 17% can be expected after implementation of a kilometre charge (12 cents).

One must be aware that the introduction of a kilometre charge of about 15 cents would be a really substantial change in variable costs. The present level of variable cost of car use is about 20 cents (for diesel and LPG cars it would even be lower: respectively about 12 and 8 cents). Adding 15 cents per km means an increase of 60% or even more in variable costs.

In summary, a considerable decrease in the number of kilometres can be expected, depending on the way of variabilisation.

5.6 Driving style

One of the options available with ICT is to differentiate the kilometre charge according to driving style. Driving style includes components such as speed, overtaking behaviour, acceleration, braking etc. This will have an effect on energy use, noise and accident-risk. Because these effects are co-determined by the type of road, a charge related to the extent of exceeding speed limits is a good indicator for the costs of traffic unsafety. This could lead to less (serious) accidents with a sufficiently progressive structure of the charge. With the current technological possibilities it is possible to distinguish several driving styles by continuously measuring speed and acceleration. Adjustment of driving style caused by this differentiated charge will lead to positive developments concerning noise nuisance, safety, fuel use, emissions and congestion.

5.7 Use of alternative transport modes

It is to be expected that the introduction of a charge per kilometre will have effects on the modal split. Public transport and bicycles will become relatively more attractive by an increase in the variable costs of the car. It is of course also possible to choose a destination more nearby, to abandon the trip or to carpool.

The aforementioned study of Muconsult shows some results concerning the expected use of public transport after introduction of a kilometre charge. A rather substantial substitution between car and public transport may be expected. Therefore, the question whether public transport has sufficient capacity to cope with this demand deserves attention. In addition, the HCG study reports an increase in kilometres travelled by public transport of about 6% compared with a reference situation, depending on the variabilisation scheme adopted. Comparing both studies, we see that the effects of the HCG study for public transport are considerably lower compared with the Muconsult results.

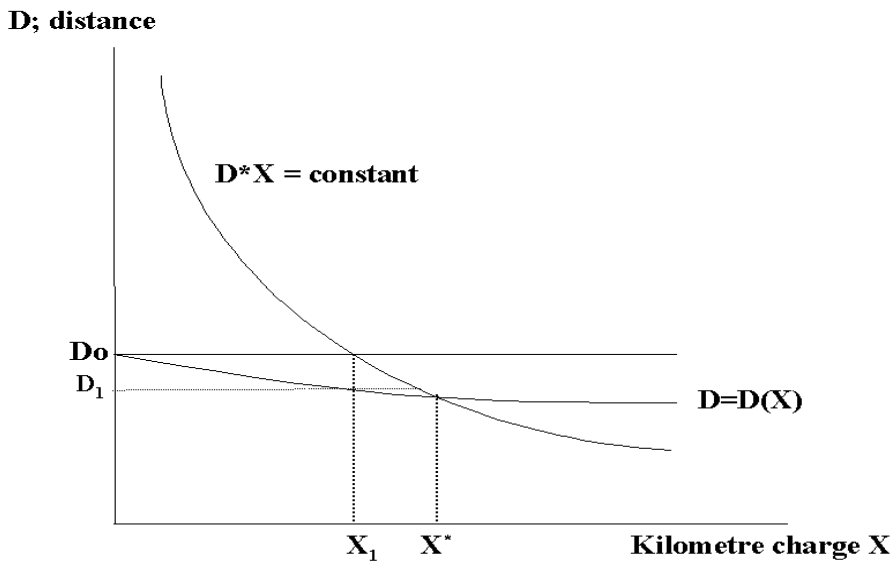
6. Four policy alternatives to introduce a kilometre charge

This section will describe the estimated effects of the implementation of a kilometre charging system. Four different alternatives of variabilisation will be introduced. The effects of these will be outlined regarding transport use, environment (emissions), traffic safety, noise nuisance and car costs. The model that has been used is known as the Scenario Verkenner (from TNO-Inro). The Scenario Verkenner (Scenario Explorer) has been designed to explore long-term developments of mobility (passengers only) for the Netherlands on a national scale and for medium and long term (up to 2050). The model works incremental, starting the process for the base data of 1990. The user may enter time-series data on themes like demography, technology, prices and regulations, culture, infrastructure and spatial development. Most of the variables may be given on a basis of regional division. The car-ownership model finds the total fleet of cars for three markets (business, first car and additional cars) using elasticities for income, car price, number and composition of households and car-use taking into account saturation levels. The transport demand model calculates number of trips simultaneously for mode and destination. For this a multinominal logit model has been developed. The model has been calibrated for the expenditure data on the year 1990. More information may be found in Heyma (1999-1, 1999-2 and Verroen 1993).

It is assumed that the kilometre charge has to compensate for the decrease in tax revenues due to the (partial) abolishment of the taxes on new cars (BPM) and on car ownership (MRB). Given this principle of budgetary neutrality the level of the kilometre charge has to be obtained using iteration.

Figure 1 illustrates this iteration process. D_0 is the level of demand in the current situation. The curve D.X=constant is the set of all combinations of demand D and the level of a kilometre charge X that yield the same level of receipts for the public sector. In the case of budgetary neutrality the level of the constant would equal the receipts that will no longer be collected by the public sector (for example the receipts of the car ownership tax) as part of the policy package. Note that this figure is based on an average km charge. The real picture is more complex because the charge will be differentiated according to type of car, type of road, driving behaviour, etc. In the iterative process we first assume that the total number of kilometres travelled remains constant. This leads to the computation of X_1 as the provisional km charge. Computing demand for vehicle kms for this level yields D_1, being lower than D_0. After a small number of iterations the charge is not far from its equilibrium value X^*.

Figure 1: Iterative process to establish the kilometre charge (demand for kilometres (D) as a function of the kilometre charge (X))



6.1 Alternatives

All alternatives are characterised by an abolishment of fixed taxes and the introduction of a kilometre charge. The fixed taxes are:

- - BPM: tax on new cars
- - MRB: tax on car ownership.

In some alternatives the BPM will be replaced by a so-called BPM_V. This is a tax that has to be paid at the moment of purchasing a car (as it is for the BPM) but the level depends on the fuel use of the car and not directly only on car price. This tax gives an incentive to purchase more fuel efficient cars. Besides, the fuel tax will be lowered till the lowest possible tariff within EU context. The following alternatives are distinguished:

- - Alternative I: complete variabilisation, both MRB and BPM will be replaced by the kilometre charge. This alternative is budgetary neutral for the government. The costs for the OBU will be included in the price of a new car.

- - Alternative II: MRB abolished, BPM replaced by a variable BPM_V with an average level of fl 5000,- per car (about half of the current level). The OBU costs are included in the price of a new car. This variant is also budgetary neutral.

- - Alternative III: MRB abolished, BPM replaced by a variable BPM_V with an average level of fl 0,- (so the BPM_V is a plus-minus regulation for the purchase of cars). There is complete variabilisation, but also an incentive is included to buy fuel-efficient cars. Again the starting point is budgetary neutrality and costs of the OBU in the price of a new car.

- - Alternative IV: Both MRB and BPM will be replaced by the kilometre charge. This alternative includes an extra incentive (extra high level of kilometre charge) for the environment. This variant is therefore not budgetary neutral for the government. In addition, the OBU will be paid by the government, which in turn will lead to an even higher kilometre charge.

Starting point for the calculations is the construction of a Reference Scenario for the year 2008. This Reference Scenario is developed from the TNO Base-scenario (see Wilmink and Korver, 1999), that is based upon the European Coordination Scenario of the CPB (Central Planning Agency in the Netherlands). In this Reference Scenario the indexes of the fixed and variable costs from 1998 till 2008 are kept constant. All other variables in this scenario are copied from the TNO-Inro Base-scenario.

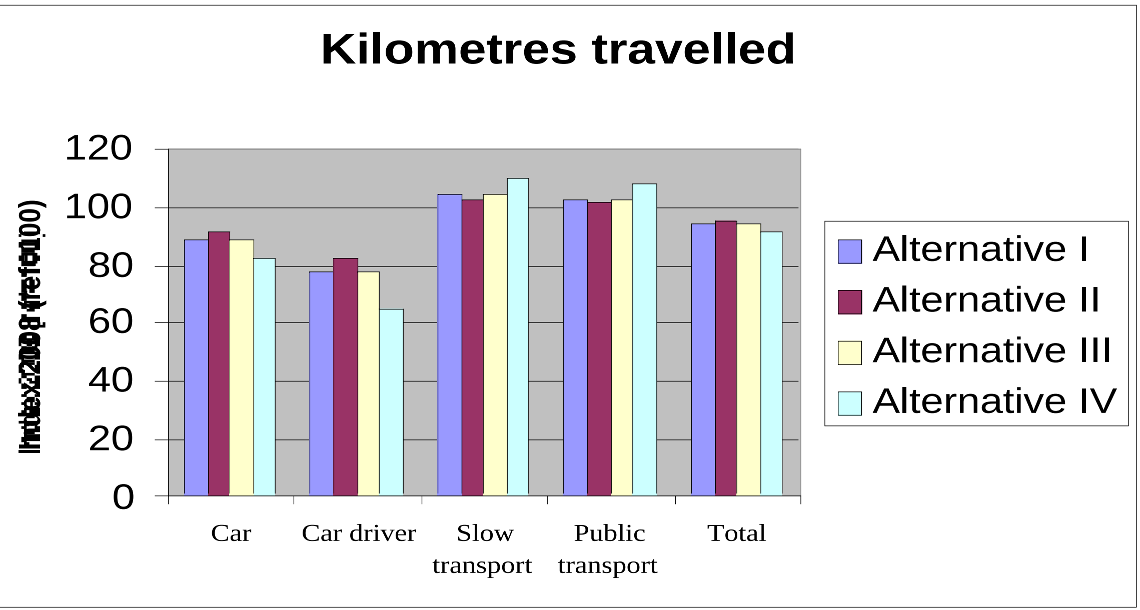
The effects of the introduction of a kilometre charge are calculated for 2008, the supposed year of complete implementation of the charge. In that year all cars should be obliged to be equipped with an OBU (except for some categories of oldtimers). The decrease in fixed costs causes a larger growth in amount of cars compared with the Reference Scenario. According to the model used this growth is 8% in the most extreme case.

6.2 Effects on transport

From Figure 2 it appears that in all alternatives the total level of person kilometres will decrease only slightly while the level of car kilometres will show a considerable decrease. It is also shown that not only the use of slow and public transport will grow, but especially also the occupancy rate of the car. This does appear from the fact that the total level of kilometres of the car driver is significantly lower compared with the number of personkms per car.

Figure 2: Effects of four alternatives on kms travelled per transport mode in 2008

(Reference 2008 = 100)



Alternative IV is having the largest impact, followed by Alternative I and III. It can be concluded that the proposed introduction of a kilometre charge has a substantial impact on car use. It is partly compensated by an increase in occupancy rate of the car and the use of bicycles and public transport.

6.3 Costs

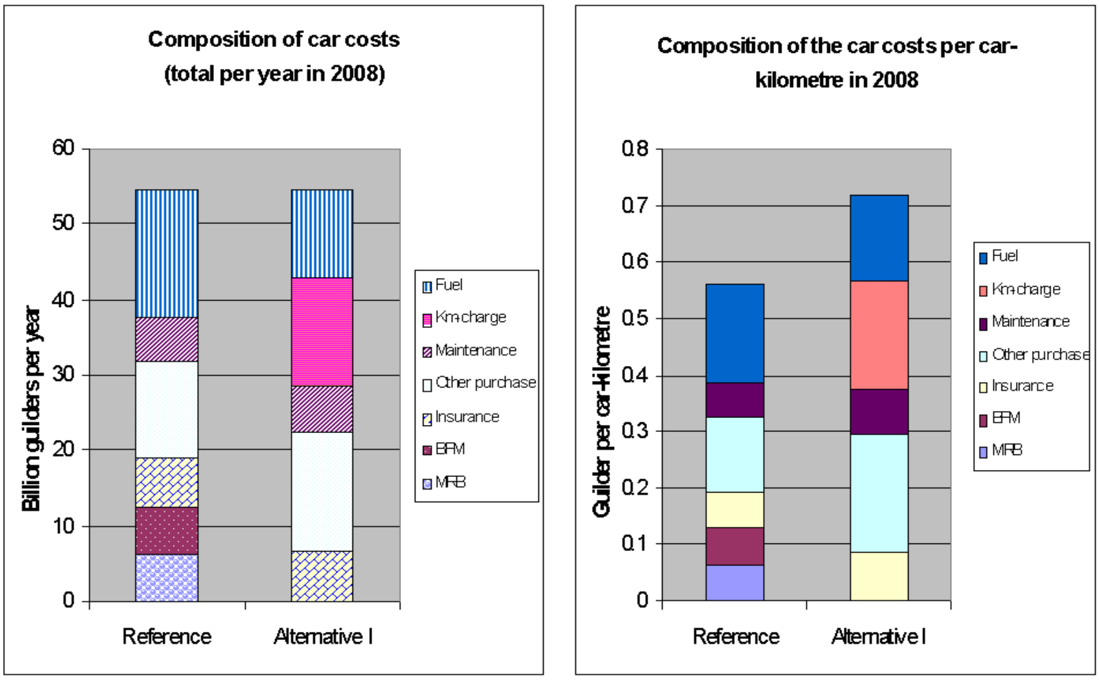
It is interesting to see what the kilometre charge will imply for the cost structure. Table 4 provides an overview of the kilometre charge, fixed and variable costs for the distinguished variants. The costs per vehicle are the total variable and fixed costs

Table 4: Overview of the total costs for an average car user.

Cost	unity	1998	Alternative			
			I	II	III	IV
Kilometre charge (average)	/km	0,000	0,191	0,142	0,191	0,264
Costs per vehicle per year	_/vhl /year	8515,-	7867,-	8069,-	7867,-	8302-
Costs per vehiclekilometre	/km	0,549	0,718	0,675	0,718	0,878
Totale costs of car driving	Bil _/year	54,58	54,51	54,61	54,51	55,97

(including the kilometre charge), divided by the number of cars. The costs per kilometre are the total fixed and variable costs divided by the total amount of kilometres. The kilometre charge shown here indicates the average level, it will (strongly) vary per vehicle. The total costs for car driving include all costs borne by car drivers. Figure 3 shows an example of the cost structure for Alternative I.

Figure 3: Overview of the fixed and variable costs for the complete car-fleet totals per year and in guilders per car-kilometre for Alternative I

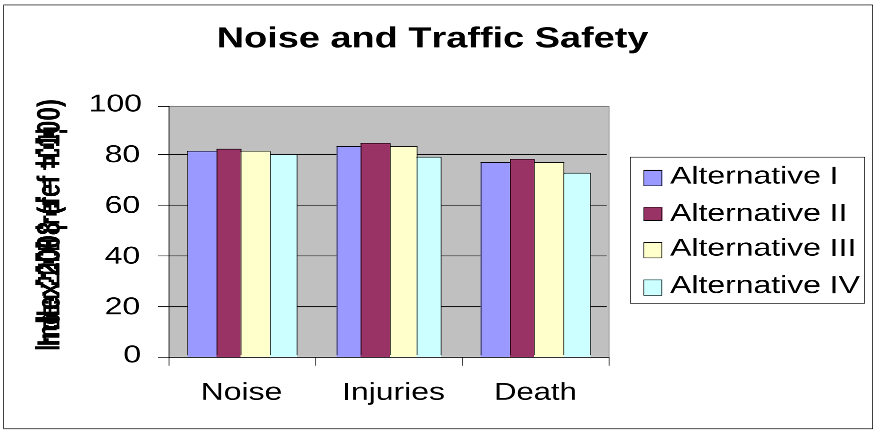


In the left picture the shift from fixed to variable costs can be seen (implementation of the kilometre charge and disappearance of MRB and BPM). The cost per kilometre will increase (see right part of Figure 3), but the total cost will remain about the same (see left part), because of the reduction of the number of kilometres travelled by car.

6.4 Environment

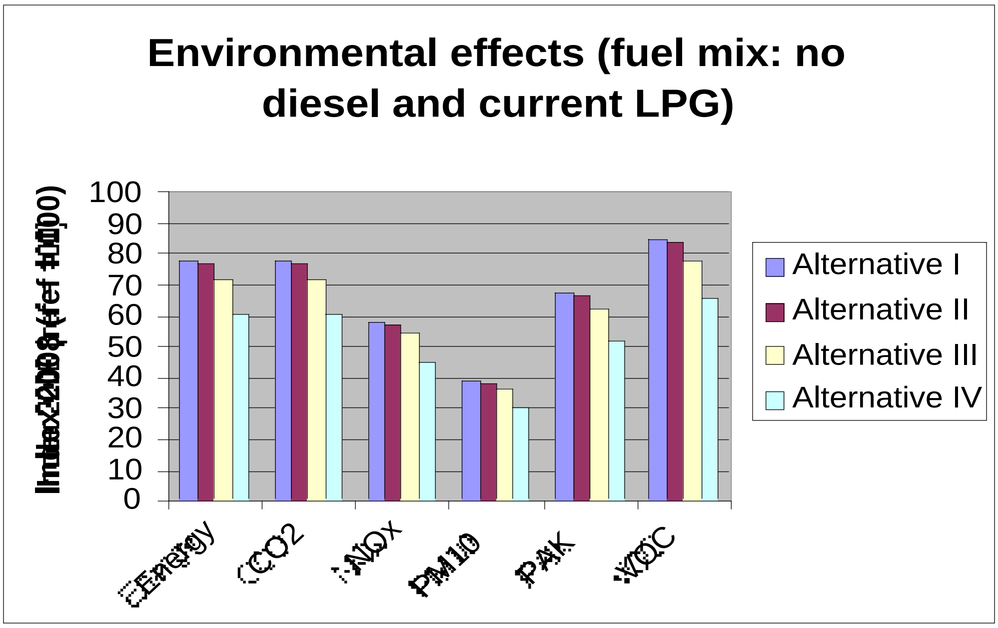
For all four alternatives an estimation has been made of the effects for energy-use, noise, emissions and death and injured people caused by accidents. The results for noise and traffic unsafety are presented in Figure 4. The effects can be explained from the decrease in car kilometres and differentiation of the kilometre charge towards unsafe behaviour (especially the speed component). These effects are derived from Peeters et al., 1996, under the assumption that the number of speed offences will decrease with 80% (crossing speed limits will become expensive).

Figure 4: Effects on noise nuisance and traffic safety of the four alternatives as index of the reference scenario



The energy-use and emissions have been based on estimations for energy- and emission-coefficients for 2010 (Geurs et al., 1998). The effects on emissions and energy use depend also on the fuel-mix and this is again dependent on the differentiation of the kilometre charge on fuel use. We identified again four possibilities of what will happen with the fuel-mix. These can be combined with the four alternatives to calculate the effects. As this is too comprehensive to be discussed here we will focus on one example (for a full overview, see Peeters et al., 2000). The fuel-mix discussed here consists of a constant level of LPG, while diesel will be totally replaced by petrol. The effects can be seen in Figure 5. Energy use and CO2 emissions will decrease with about 25% for alternatives I,II and III, while alternative IV shows a decrease of 40%.

Figure 5: Environmental effects for a fuel-mix without diesel; petrol takes over this share and LPG remains constant.



A general conclusion which can be derived from all combinations is that energy use can be reduced with 20% till 40% (compared to the reference scenario). This last figure implies a 6 cent higher kilometre charge to compensate for the missed tax revenues from MRB, BPM and excise duties. Emissions can be reduced until 70%, while noise nuisance and traffic unsafety decrease with about 20%. For emissions it holds that the effect of alternative I is the least. This effect becomes larger for the successive alternatives II, III and IV.

The effect on congestion depends strongly on the extent of differentiation of the charge towards place and time and the possibility to anticipate on this. This has not been addressed in the present study.

6.5 Uncertainties

From section 5 we already learned that various uncertainties can be identified about the effects of a differentiated kilometre charge. In particular, knowledge on the effects on car ownership and the choice of car type as a function of the structure of prices is underdeveloped. Another relevant aspect concerns the response of the automobile industry: to what extent will it shift its priorities in the technological development of passenger cars. Also the price setting behaviour of the automobile companies may play a role. International comparison of prices of cars indicates that in countries with high taxes on new cars lower margins are used than in other countries (Verboven 1998). This would imply that a reduction of taxes on new cars does not necessarily lead to an equal reduction in the prices paid by the consumers.

7. Implementation issues

In its recent policy document the Ministry of Transport (Ministerie van Verkeer en Waterstaat, 2000) has announced its intention to introduce an electronic kilometre charge in the year 2010. The intention has been expressed to introduce it in a budgetary neutral way. The response of the general public and of interest groups has been rather favourable thus far. However, the successful introduction of such a scheme depends on a large number of issues, some of which will be shortly discussed here.

1. *Technological feasibility*. The system must work and probabilities of technical errors must be very low. This criterion seems to be met given the fact that a rather similar system has been introduced for trucks in Switzerland. It is expected that also Germany will introduce a similar system for trucks within the years to come to replace the current Eurovignet system. Given the opportunities to benefit from learning effects with trucks, technology will most probably not be a major bottleneck for the introduction of a kilometre charge for passenger cars.

2. *Fraud.* The system must achieve levels of fraud-proneness that are comparable to or better than the present fraud levels with car related taxes. Here again, experiences with the truck variants will be important. Potential problems relate to the kilometre recorder. Stories about fraud with kilometres by garages selling used cars are well known. Ingredients to counter this type of fraud would be to use electronic kilometre recorders and to employ the GPS data to enable the OBU to check distances travelled. If irregularities would be detected it would convey a signal to the DSRC portals. Another type of fraud relates to the installation of the OBU. Special licensing of garages would be needed. A simple way of fraud would be to drive with an empty smart card. This would be detected by the OBU so that it will again send a signal via the DSRC. The information on distances travelled would be stored in the OBU so that there would always be a possibility to retrieve the necessary information. A final element to prevent fraud is the existing annual check up of cars by licensed garages.

3. *Privacy.* The privacy issue usually emerges as a consequence of measures to prevent fraud. The system outlined here does not entail the central registration of trips made by all cars. All information is stored in the OBU and remains in the car. Only when the OBU detects irregularities it will send signals via DSRC.

4. *Cost of implementation.* The current price of the OBU is high (about dfl 2000). For trucks such an expenditure can rather easily be absorbed in the total price, but for passenger cars it must be considered as a large amount of money. Much depends on the rate of adoption of this type of system for trucks in various countries. This would make it a mass product so that it would become cheaper. Much cheaper OBU's are possible but this means central gathering of information (and thus a large privacy problem) and a much higher risk for fraud. Further, the OBU may be used as the hardware of car-navigation systems and other modern incar systems. This will save the consumer a substantial costs.

5. *Standardisation.* Given the international character of road transport in Europe standardisation of the charging system between countries will be of utmost importance. This holds true in particular for freight transport, but also for passenger transport the situation must be avoided that special measures are needed when cars enter a neighbour country. Note for example that about 10% of the kilometres of the average Dutch car is made in other countries. The proposed system will adhere to the current European standards on DSRC communication.

6. *Foreign cars.* For cars from other countries that do not have a kilometre charge system several options remain. The first is they have not to pay for the kilometre charge. This is much the same as in the current situation in the Netherlands, where foreign cars do not have to pay the fixed taxes. Note also that when cars cross a border, the OBU is informed via its navigation system and (for the Swiss system) by DSRC communication so that the charge level can be adjusted.

7. *Opposition by groups negatively affected*. The introduction of a kilometre charge will have negative effects on drivers who tend to travel above average numbers of kilometres, the others will be positively affected. Potential bottlenecks may be found in some economic sectors that may claim that the costs will increase because business trips will become more expensive. Another potential bottleneck may be found in the car rental sector. The profitability of this sector is based on spreading the fixed costs of car ownership among a large number of renters. When fixed costs would decrease and variable costs would increase part of the clientele would find that it is more profitable to buy one's own car (first or second).

8. *Trust.* The kilometre charge would be part of a package where higher variable costs would be introduced in combination with reductions elsewhere. Communication about these aspects would be essential to build trust.

9. *Misperceptions of consumers.* Myopic consumers will buy a car on the basis of the price. This holds true for both new and used cars. Given the shift from fixed to variable costs the variable costs will have to play a larger role here. Thus, standardisation of information on the complete costs of cars will be needed. In this respect the car is not different from other durable goods like fridges or mobile phones where similar information on fixed and variable costs is compulsory.

10. *Evolutionary introduction*. Gradual introduction may help to avoid bottlenecks in the start-up phase such as limited capacity of garages to install OBU's. This would call for tax structures such that early adopters would benefit from voluntary adoption.

11. *Linkage of OBU with other applications*. Given the use of GPS in the system the linkage with navigation systems is an obvious option. Another opportunity would be to add features in the OBU such that it will render services to users of business cars. About 40% of all new cars in The Netherlands are business cars (Rietveld and Van Ommeren, 2001). Having at one's disposal a business car leads to a substantial increase of taxable income for the income tax. An OBU related system would make it easier for drivers to demonstrate that the car is not used for private purposes so that their taxable income can be reduced.

8. Concluding Remarks

This study shows that the introduction of a differentiated kilometre charge can lead to a reduction of environmental pollution caused by car traffic (depending on the kind) with 20% till 70%. In addition, a significant decrease of congestion on roads can be expected. In most cases the average costs for consumers will not rise.

When one wants to keep the total burden for the car driver constant the introduction of a kilometre charge has to be combined with the abolishment of the tax on ownership (MRB) and on new cars (BPM) and the introduction of a BPM_V (tax depending on the fuel use of a car). Implementation of these measures will decrease the total number of car-kilometres with 10% till 25% compared with a reference situation, while the total number of kilometres travelled will show a smaller decline. This is caused by an increase in the use of public transport and non-motorised transport.

More in detail the following results can be derived from this study:

• • A kilometre charge together with the proposed fiscal measures will result in a more efficient use of the car (in the form of an increased occupancy rate).

• • The kilometre charge can lead to a reduction of: 30% in emissions and energy use, 15% in noise nuisance and 20% in the number of traffic accidents.

• • Despite a clear decrease in car-kilometres, the total number of kilometres travelled will only decrease with 5% till 9% compared with the Reference Scenario. This reference picture foresees a growth of more than 10% in number of car-kilometres between 1999 and 2008.

• • The total number of cars will grow with 6% to 8%.

• • Costs for the government consist of organisation, construction of the roadside equipment and managing the system. Benefits are foreseen by the disappearance of the border effect (caused by reducing the current relatively high excise duty on fuels), smaller investments in road capacity, less costs for health care and increased occupancy rates in public transport.

We do want to state though that further research is strongly recommended towards the effect of variabilisation on car ownership and the composition of the car-fleet. This aspect has insufficiently been studied in the Netherlands and the lack of reliable prognoses leaves a lot of room for speculations. These discussions prevent from proper decision-making regarding the kilometre charge.

Other aspects that deserve attention concern the environmental and energy consequences of the production and disposal of cars. This has been studied among others by Bouwman (2000) and Hayashi et al. (2001). They demonstrate that these life-cycle considerations have non-negligible consequences.

Finally it is recommendable to carry out further research towards the possibilities and effects of the differentiation of the kilometre charge. Exactly establishing the foundations of the charge, the tariffs and the estimation of effects and revenues of the kilometre charge are of crucial importance to give reliable insight in an early phase into the financial consequences of a kilometre charge for the government.

Acknowledgement

This paper is partly based on research carried out for the Netherlands Society for Nature and the Environment towards the effectiveness and feasibility of a kilometre-charge. The authors wish to thank Duco van Dijk, Ton Sledsens and Jan de Vries for their useful comments.

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Appendix 1: List with abbreviations

BPM: Dutch tax on new cars, to be paid at the moment of purchase

BPM_V: substitute for BPM in the new situation, tax to be paid at the moment of purchase but depending on the fuel use of the car

DSRC: Dedicated Short Range Communication, this system makes it possible to exchange data between very short distances using microwaves.

GPS: global positioning system, uses satellites to state positions very accurately

LPG: Liquefied Petroleum Gas

MRB: Dutch tax on car ownership

OBU: On Board Unit, device able to communicate at least with out of car equipment (such as portals). More advanced OBU's are also able to register data, calculate the charge and devalue smartcards