Tradable driving rights in urban areas: their potential for tackling congestion and traffic-related pollution

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TRADABLE DRIVING RIGHTS IN URBAN AREAS: THEIR POTENTIAL FOR TACKLING CONGESTION AND TRAFFIC-RELATED POLLUTION

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31 October 2007

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Abstract

Congestion pricing as a transport demand management measure is difficult to implement because most of motorists expect a deterioration of their welfare. Tradable driving rights (TDR), that is allocating quotas of driving rights for free to urban inhabitants, could be a more acceptable alternative. This mechanism provides also a supplementary incentive to save whether trips or distance travelled by car, because of the possibility of selling unused rights. A complete system of TDR is designed in detail, aiming whether at reducing trips or vehicles-kilometres, in order to control congestion, or the same target modulated on the basis of the pollutant emission categories of vehicles in order to control atmospheric pollution. An assessment is carried out on the Lyon urban area, which points at some welfare distributive issues between motorists and the community, when compared with conventional congestion pricing.

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Introduction

This paper explores in detail a transport demand management (TDM) measure which could deal with congestion and pollution caused by automobile traffic, as they are major and recurring concerns in urban agglomerations all over the world. Taking the economist's perspective, these phenomena reflect over-consumption of scarce goods, i.e. the road capacity in the case of traffic or the clean air in the case of atmospheric pollution: this over-consumption is the result of the under-pricing of these goods.

Since the seminal work of Marshall and then Pigou (1920), it has been established in standard economic theory that regulation by pricing is an efficient means of allocating a scarce resource. This issue is crucial for public goods which are subjected to congestion, for example in the transport sector where pricing is the proposed means of regulating congestion (Walters 1961; Vickrey 1963). The same rationale applies to the regulation of traffic-related pollution.

This is why, in response to congestion and pollution in urban areas, the TDM measure favoured by economists is road user charging or congestion charging which are both implemented by road tolls. In spite of the success of the London Congestion Charging scheme (since 2003) or the successful experiment in Stockholm (in 2006), social and political resistance to urban road pricing is still strong.

Although it is accepted that responding to congestion by introducing congestion pricing increases the welfare of community as a whole, redistribution occurs (Baumol and Oates 1988; Hau 1992). Surplus changes occur in the welfare of different categories of actors from before to after the introduction. The situation of motorists who forsake the road deteriorates as they switch to alternatives which they found less beneficial before the introduction of the road pricing. The situation of most of the motorists who remain on the road also deteriorates, in spite of higher speeds, as they are subjected to an increase in monetary cost which exceeds the value of their time saving. The situation of a minority of individuals improves as a result of their high values-of-time. Finally, the public authorities who collect toll revenues become wealthier.

So, in general, there is little chance of a congestion charge being accepted, unless motorists are convinced that the public authorities are benevolent and that they will distribute the resources collected efficiently and equitably; for example, by a reduction in taxation targeted at motorists or by financing new transport services which would compensate the first group of motorists referred to above.

However in the light of these difficulties, another instrument which combines economic incentives and regulation by quantity, namely marketable or Tradable Permits (TPs), might be of interest. This category of instruments is part of a wider one, namely transferable permits. According to a general definition given by O. Godard (OECD 2001), transferable permits cover a variety of instruments that range from the introduction of flexibility into traditional regulation to the organization of competitive markets for permits. These instruments have in common: the setting of quantified physical constraints in the form of obligations, permits, credits or rights allocated to target groups of agents consuming scarce resources; and the permission granted to the agents to transfer these quotas between activities, products or places (offsetting), periods of time (banking) or to other agents (trading, hence "tradable permits").

These tradable emissions permits (or quotas[1]) are frequently referred to as "pollution rights", implying that those who can afford to are allowed to purchase the right to harm the environment. However, the allocation of emission quotas does not involve the creation of "pollution rights", but the restriction of these rights when previously they were unlimited. Making these quotas "tradable" therefore amounts to introducing flexibility and minimizing the total cost to the community of reducing emissions. For instance currently the European Trading Scheme applies tradable quotas of CO_2 emissions to about 12,000 energy-intensive fixed sources within the European Union.

The allocation of quotas for trips or vehicle-kilometres to motorists within a given urban area has been proposed, with the possibility of these quotas being tradable (Verhoef an al. 1997; Marlot 1998). An initial allocation would guarantee a free limited amount of travel – which would improve the acceptability of the mechanism in comparison with conventional road pricing – while any automobile travel beyond this allocation would be subjected to the equivalent of a road use charge because of the need to purchase additional permits. A credit-based congestion pricing mechanism has been proposed by Kockelman and Kalmanje (2005) by which motorists would receive a monthly allocation in the form of credits (in principle monetary), which can be used to travel on a road network or within a zone with congestion charging. The motorists would therefore have nothing to pay if they did not use up their allocation: beyond this allocation, they would be subjected to the congestion charging regime. Those who failed to use up their allocation completely would be able to use their credits later or exchange them for cash.

This paper will deal with the interest of tradable permits in urban travel demand management. It has been shown theoretically that this type of instrument guarantees the achievement of the quantitative objective of limiting pollution at minimum cost. Furthermore, this instrument is particularly appropriate in situations of uncertainty with regard to the response of demand, as is the case in transport. It also provides a way of separating issues to do with the allocative efficiency of pollution and congestion abatement efforts from equity issues by means of the initial allocation of quotas. The paper will then show the types of adverse impact this instrument may be appropriate for in urban areas and what targets may be set.

To the best of our knowledge, none of the proposals quoted above is detailed enough for it to be possible to judge whether this type of measure could be applied in urban areas. In this context, however, "the devil is in the detail": from the specification of the implementation of TPs for urban travel demand management, it will be shown which configurations are possible and relevant. The applicability of this type of instrument will then be demonstrated by referring to a detailed example, which will then be evaluated.

1 Why are tradable permits of interest in urban areas?

Firstly the theory of tradable permits will be briefly recapped. Given TPs properties, nuisances within urban areas that are appropriate for TPs implementation will be identified. Then potential targets will be analysed and finally matched to nuisances previously identified.

[1] The terms quota and permit will be used interchangeably in the rest of this paper.

1.1 Theory

The economic theory behind pollution permit markets can be traced back to the work of Coase (1960) on external costs, followed by that of Dales (1968) on regulating water use, and the formalization of pollution permit markets by Montgomery (1972).

A system of tradable permits equalizes the marginal costs of reduction between all emission sources. Under certain assumptions this is a sufficient condition for minimizing the total cost of achieving a given emissions reduction objective (Baumol and Oates 1988). This result is obtained independently of the initial allocation of rights: it should be stressed that this makes it possible to separate the issues of efficiency and equity.

However, Stavins (1995) has shown that when transaction costs are involved – the search for trading partners, negotiation, decision-making, follow-up and compliance with the rules – the initial allocation of rights affects the final balance and the total cost of reducing emissions. The authorities may therefore attempt to reduce these transaction costs, for example by avoiding finicky regulations or by facilitating the activity of intermediaries between vendors and purchasers (Hahn and Hester 1989; Foster and Hahn 1995).

The use of transferable permits is not new. They have been used in the fisheries, and in the fields of construction rights and water pollution. The US "Acid Rain" scheme has been developed as a large-scale system of tradable sulphur dioxide emission permits (Godard 2000). An appraisal of these experiments has made it possible to identify the principal criteria of success for such systems and the associated legal and institutional pitfalls (OECD 1998, see below).

With regard to the quantitative reduction objective, the essential difference between taxes and permits lies in the fact that in practice the public authorities do not possess full information on the reduction costs for the different agents. With a permit-based approach, achieving the quantitative emissions reduction objective is guaranteed, but there is no guarantee with regard to the level of the actual marginal costs of reduction. On the contrary, in the case of the tax, the marginal cost of reduction for each agent is fixed by the tax level, but there is no guarantee with regard to the quantitative level of emissions reduction.

This uncertainty makes it difficult to make a choice, as errors as regards anticipated damage or the reduction costs for agents, particularly with regard to the distribution of efforts over time and between agents, may be very costly to the community. Nevertheless, a number of criteria may be of use when making this choice (Baumol and Oates 1988).

A first criterion for the appropriateness of permits is whether the damage to the environment is in danger of increasing very rapidly or becoming irreversible when certain emission thresholds are reached or exceeded. In this case, tradable permits provide a guarantee of achieving the quantitative emissions limitation objective while minimizing the cost of evaluation errors in comparison with the tax. The problem of greenhouse gas emissions is a particularly good example of this situation. Another, in the field of transportation, is the case in which congestion may, in the short term, result in hyper-congestion which generates large-scale waste for the community.

A second criterion is whether agents are more sensitive to quantitative signals than price signals, particularly if the price-elasticity of demand is low in the short or medium term. In this case again a permit system is more appropriate.

For example, emissions from travel may be reduced by various means: changing driving style, reducing vehicle-kilometres of travel (by increasing the number of passengers in vehicles, reorganizing trips or changing the locations of activities); by changing one's vehicle or changing mode in favour of one which consumes less energy. Some of these actions may be implemented in the short term, while others, such as changing one's vehicle, changing one's place of work or of residence, may take much longer. The result of this is elasticities which are generally low in the short term and considerably higher in the long term. For example, for fuel consumption, the price-elasticity values are between –0.3 in the short term[2] and –0.7 in the long term (Goodwin 1988).

Nevertheless, the choice between taxation and permits requires a case-by-case analysis. A general solution to this problem of uncertainty with regard to the costs of emissions reductions has been proposed by Baumol and Oates (1988, pages 74-76), on the basis of an idea developed by Roberts and Spence.

If the regulator does not put enough permits on the market (for a given year or a given sector), the free play of the permit market will result in an excessive price. The regulator can then introduce a payment in full discharge *t*, on the principle that any polluter has the right to emit more than the quantity of pollutant permitted by his/her permit by paying the charge *t* for these additional emissions. [3]In this case, as soon as the price of permits exceeds the level *t*, it is in the interest of polluters to pay the payment in full discharge.[4] The upper bound of the permit price will therefore be equal to *t*. This is the hybrid solution which combines the allocation of permits and a payment in full discharge. It is to be applied when the regulator must make decisions either with regard to the temporal distribution of efforts (for example annual objectives) or with regard to the distribution of this effort between the different actors or sectors.

Furthermore, a third criterion that is an important factor for the effectiveness of TPs is the heterogeneity of the agents involved in the system. This means that the marginal costs of abatement must be sufficiently different between agents in order to allow benefits from trading permits thereby making the market function effectively.

In our context the marginal nuisance reduction cost curves are highly varied, and, in particular, rise as one moves from urban to suburban and then to rural settings. On two essential points, namely changes in the locations of activities and changes in transport mode, the possibilities for action differ very greatly in both nature and degree on the basis of the residential locations of the individuals in question (urban, suburban, rural). Changes in the locations of activities in order to reduce the distances between different activities are much easier to make in urban areas than in suburban or rural locations, as a result of the density of available activities: changes are possible in the short term for activities where the location imposes little constraints, such as shopping or leisure; reducing distances between home and work is easier in a conurbation which provides a high density of job and housing opportunities. Likewise, the large amount of trip flows which results from the high density of activity locations means that public transport which provides an alternative to the private car is more frequently available in urban areas.

Finally, last but not least, in political terms, systems where permits are allocated free of charge may be seen as a means of avoiding an additional tax, and this can enhance the

[2] i.e. a 10% increase in price would lead to a 3% reduction in fuel demand.

[3] That is to say in lieu of having to buy permits at a price p which could rise to a too high level, the emitter could be discharged of his/her obligation to render permits by paying the charge *t* for each unit of emission exceeding the rights he/she holds.

[4] This does not apply to the current European Trading Scheme as the penalty is not a payment in full discharge.

acceptability of the new instrument. With this free allocation, economic agents have a supplementary incentive to save whether emissions, trips or distance travelled, beyond their initial allocation of permits because they can sell unused permits and then get tangible reward for their “virtuous” behaviour.

The main arguments against the use of permits in the transport system are the cost of administration over a large number of mobile sources and the transactions costs of quotas transfer. However this issue is similar in the case of electronic road pricing and is now better addressed, as we will see, thanks to electronic technology which is affordable today.

1.2 Appropriate nuisances for urban areas.

Two main criteria can be used to judge the appropriateness of transferable permit systems – the ability to impose a quantitative constraint or right within a specified space and time, and the ability of agents to transfer all or part of these quantitative obligations. These criteria can be applied initially to the main nuisances associated with transport activity, i.e. greenhouse gas emissions, regional pollution, noise and congestion.

Space-time equivalents for greenhouse gas emissions occur at the level of the planet, i.e. a ton of CO_2 has the same greenhouse effect irrespective of where and when it is emitted. Thus this issue is a global matter that goes far beyond the urban scale: the relevant market for such TPs is a world one and this will not be addressed here. While several proposals address the unitary vehicle emissions of automakers’ fleets (Wang 1994; Albrecht 2000), a proposal for tradable fuel permits for drivers has been made by Raux and Marlot (2005).

In other instances such as local or regional air pollutants[5] it is possible to set precise and measurable targets for aggregate emissions. It is the sum of the individual outputs of agents that produces the overall output. It is also possible to establish space-time equivalents for air pollution for which permits can be traded within a geographical area. Since several local or national health regulations prescribe limits for air pollutant concentrations, this may require a quantity-based approach.

However, this does not apply to noise whose level does not increase linearly with the number of individual emitters.

Congestion is another area where limits may be made explicit. If the local policy is not to increase road capacity, a quantity constraint could be imposed on road traffic. Strictly speaking, space-time equivalents of congestion cannot be defined very broadly since an hour lost at a given time in a given location is not equivalent to an hour lost in another area or time. An efficient scheme would thus restrict trading of driving rights to the users of say a corridor during a limited time span. However, congestion primarily generates network interaction effects: congestion on one section of road makes drivers choose another route in order to save time. Congestion also generates rescheduling interaction effects: congestion at one period makes some drivers decide to drive earlier or later. Because of these two kinds of interaction the trading of driving rights could be extended between different locations within a same urban network and between different times and even days. The equivalence between driving rights could be fine-tuned by weighting them differently according to the level of congestion.

[5] Primary gases in the case of air pollutants such as CO, SO_2, NOx and VOC. Secondary chemical reactions, such as ozone formation, are not considered.

Another scarce resource indirectly related to transport activity is public parking space. Here again if the local policy is to not increase the amount of public parking space, a quantity constraint could be imposed on its use. However, it is clear that for parking there is no broad interaction as in the case of congestion. The market would be restricted to small scale areas (because generally two parking places are only equivalent when they are within walking range).

1.3 Potential targets for TP implementation in urban areas

On the demand side the congestion and environmental impacts of transportation stem from,

- technical characteristics of vehicles (energy source, unitary consumption, and pollutant emissions) and fuels,
- ownership and intensity of vehicle use (travel as a function of economic and social trends),
- land use (location of activities and its impact on distances travelled).

There is potential for controlling nuisances arising from transport in all these areas. However among these, some are obviously beyond the scope of local urban governments. This is the case for the regulation of unitary vehicle emissions and fuel standards (for a survey on TP applications in these areas see Raux 2004).

Car ownership. In 1990 a scheme of car-ownership rationing involving auctions of a limited number of certificates of entitlement to purchase a new car was initiated in Singapore. The number of certificates is determined each year on the basis of traffic conditions and road capacity and the certificates are issued each month (Koh and Lee 1994). Chin and Smith (1997) showed control of ownership to be a useful instrument when automobile demand is inelastic and the social cost function is steep. Compared with price controls, quantity control reduces the welfare loss arising from any misperception of optimal equilibrium by the authority.

Car use. This can be an intermediate solution for controlling congestion. Daganzo (1995) proposed a congestion reduction scheme based on a "hybrid between rationing and pricing". This can be seen as a quota system, without the quotas being transferable. The system was modelled using the San Francisco Bay Bridge corridor by Nakamura and Kockelman (2002) who showed the difficulty of finding a combination of tolls and rationing rates which would benefit all groups of travellers. Other proposals involve setting quotas for vehicle kilometres travelled (VKT) or trips within a given urban area for motorists that could be transferred among them, as already referred to in the introduction.

Parking use. When it comes to selecting targets in order to regulate the road externalities mentioned above, parking rights may also appear to be a promising instrument. However road externalities are created by vehicles that move while parking policy basically addresses vehicles that are stationary. For instance an excessively restrictive parking policy in residential areas would generate additional vehicle traffic as a result of vehicles moving elsewhere to escape the policy. In areas that are similar to a CBD in which jobs rather than residences are concentrated, the implementation of parking rights would interfere with or even duplicate driving rights with the same objective. These drawbacks mean that parking right markets do not merit further analysis (for a more detailed analysis see Verhoef and al 1997).

Car pollutant emissions. Some of the atmospheric pollutants result from the composition of fuels and therefore may be tackled by applying TPs to fuel standards (see above). The use of lead as an additive in petrol is being phased out in developing countries and has also been the subject of a successful application of TPs in the USA (for an overview see Raux 2002a). Sulphur dioxide (SO_2) emissions are also covered by standards on the basis of the sulphur content of fuels.

However, other pollutants are produced by the inefficient burning of fuel in vehicle engines and ineffective filtering of exhaust gases. This category includes nitrogen oxides (NOx), hydrocarbons (HC) and particulate matters. For example, in Europe, unitary vehicle emissions are regulated by the Euro standards which apply to new vehicles put on the market. Table 1 gives the Euro values for private cars (class M1). It shows that between the Euro IV standard and Euro I standard the permitted levels for HCs and NOx, vary in a ratio of 1 to 10 for petrol vehicles and 1 to 3 for diesel vehicles. Particulate emissions standards have so far only been imposed on diesel vehicles (a ratio of 1 to 6 between Euro IV and Euro I) but the Euro V standard, which was still under discussion at the end of 2006, will introduce limits for petrol vehicles too.

M1 petrol vehicles	Date of application for new vehicles	HC (in CH_4 equivalent)	NOx (in NO_2 equivalent)	Particulate matters
		g/km	g/km	g/km
Euro I	1993	0.97 (HC+NOx)	0.97 (HC+NOx)	
Euro II	1997	0.5 (HC+NOx)	0.5 (HC+NOx)	
Euro III	2001	0.20	0.15	
Euro IV	2006	0.10	0.08	
M1 diesel vehicles				
Euro I	1993	0.97 (HC+NOx)	0.97 (HC+NOx)	0.14
Euro II	1997	0.7 - 0.9 (HC+NOx)	0.7 - 0.9 (HC+NOx)	0.08 - 0.1
Euro III	2001	0.56 (HC+NOx)	0.56 (HC+NOx)	0.05
Euro IV	2006	0.30 (HC+NOx)	0.30 (HC+NOx)	0.025

Source: Hugrel and Joumard 2006

Table 1: European road vehicle emissions standards

Standards of this type can thus provide a basis for regulating the intensity of vehicle use with reference to their pollutants emissions class. In practical terms, the number of rights required to use a vehicle could, all other things being equal, be varied according to the vehicle's emissions category. It is this type of modulation which was used in the Ecopoints system which was applied to lorries crossing Austria until the end of 2006 (for a survey of this experiment, see Raux 2002a).

Land-use. In scattered settings, public transport is not viable so trips are usually made by car and distances travelled are longer. Land use is generally managed through regulation, however, there have been proposals for applying tradable permits to real estate developers on the basis of the travel volumes that their projects will generate (Ottensmann 1998).

However, to do this, it would be necessary to identify traffic generators (for example, shopping centres, industrial or small business zones) and it poses many market organization problems, in particular with regard to minimizing transaction costs and making trading possible, not only within a conurbation but also between different conurbations.

1.4 Matching nuisances reductions to targets

Targeting VKT with an adjustment according to emission category may be particularly appropriate for local and regional pollutant emissions, (see Table 2). Encouraging the use of less polluting combustion engine technologies is a way of reducing harmful tailpipe exhaust emissions per kilometre driven. Targeting only VKT or trips has the drawback of rationing travel, while being less optimally linked to pollutant emissions, since there is no incentive to shift to cleaner vehicles.

Targets / *Nuisances*	VKTs adjusted according to emission category	End user VKTs or trips	Land use	Car ownership
Local / regional pollution	xxx	x	xx	x
Congestion		xxx	xx	x

From x = low to xxx = high level of appropriateness

Table 2: Appropriateness of TP targets for different nuisances in urban areas

Regarding congestion, the most efficient and decentralized incentive is on end-user VKT (or even trips on specific corridors or through an area). End-users as the final decision-makers can modify their travel choices, activity locations, or choice of vehicle. However this has the same basic drawback of rationing travel (this will be addressed below).

For both nuisances, regional pollution and congestion, controlling land use is in principle an attractive way of reducing distances travelled, but it is controversial: it has still not been proven that it is possible to reverse the tendency to travel longer distances by compacting locations again. However the spatial concentration of activities yields more opportunities for cost-efficient transport alternatives that are less energy consuming such as mass transit.

Car ownership is another indirect way of controlling car travel but the linkage with actual use and hence congestion or pollutant emissions, is very crude.

From now on we will develop the specification of the implementation of TPs for urban transport demand management.

2 Specifications

This section will outline specifications for the implementation of tradable permit markets for urban transport demand management.

The purpose is twofold: to limit the increase on the one hand of vehicle-kilometres travelled (VKT), particularly during peak periods, and on the other hand of atmospheric pollutant emissions from vehicles. The ideal, from an efficiency point of view, would be to target VKT with the ability to make distinctions on the basis of time and space (congestion) and the type of vehicle (atmospheric pollutant emissions).

However, the limited possibilities of affordable technology mean that a compromise must be accepted with regard to this objective. We shall begin, therefore, by taking stock of technological possibilities at the present time and the near future. This will be followed by an examination of the conditions which a tradable permit system must satisfy in order to be implemented successfully.

2.1 Existing and conceivable technologies and their costs

The most mature technology at the present time is roadside Electronic Toll Collection (ETC). This is based on an on-board electronic tag which uses Dedicated Short Range Communications (DSRC) to dialogue with roadside readers. The dialogue between the two, in the most simple version, is used to identify the vehicle and transmit information about the transaction to a central computer in order to invoice the owner of the vehicle. This procedure requires prior registering of both vehicles and drivers. The roadside reader must also be fitted with a video enforcement system (VES) in order to recognise the number plate of those vehicles for which the transaction does not succeed (because of fraud or for other reasons).

A more sophisticated version involves debiting on the fly a preloaded smartcard or credit card that is inserted in the on-board unit (OBU). Objections with regard to the protection of privacy can be overcome by allowing the anonymous purchase of cards which have already been loaded with units.

A system of this last type is used for the Singapore Electronic Road Pricing (ERP) system which was introduced in September 1998 to replace the manual toll payment scheme in operation since 1975. This covered the central business district known as the Restricted Zone (RZ). The new system covers the RZ and a set of major expressways. To begin with, in 1998, 32 gantries were installed and 674,000 In-vehicle Units (IU) were distributed free of charge with a total investment cost of US$ 114 million (Menon and Chin 2004). Drivers use preloaded CashCards that they can buy anonymously in retail shops and ATMs. The CashCard is inserted into the IU and debited at each crossing through a gantry. Annual operating costs stand at US$ 9 million for roughly 6 million daily transactions in 2003. The average monthly level of fraud is less than 0.5% of all transactions. The owners of new vehicles must now purchase their IUs at a cost of US$ 69 (Menon 2000).

A second type of toll collection technology, based on a vehicle positioning system (VPS) that uses satellites (the international GPS system or the European Galileo system), is currently emerging. A well-known example is the TollCollect programme for lorries on the German motorway network. This technology is based on an on-board unit (OBU) which contains a GPS positioning device which dialogues with a constellation of satellites. This type of technology represents the most effective road toll collection system in that it can track the movements of vehicles so the exact distance travelled can be charged, at a rate which may be varied according to the location and the time of passage.

Although from the technical point of view this system requires no roadside equipment, currently it would nevertheless be extremely costly to implement. For example, the estimated cost of the OBU is between €200 and €400 (including installation cost). Furthermore, in order to optimize the cost of the system, all the vehicles which can potentially be charged must be included in the system at the outset: complex and costly manual procedures which duplicate the electronic system are required to process occasional users. Lastly, the possibility of permanently tracking vehicles raises obvious issues with regard to protecting the privacy of car drivers. However, it is probable that these initial problems will be overcome and ultimately acceptable and cost-efficient technologies will be developed.

On the basis of these technical possibilities and their present-day costs, two possible types of application can be envisaged:

- the first application would use well-proven technology based on roadside ETC (RS-ETC) and would aim to cover all motorized vehicle *trips* in the zone covered by the traffic restriction scheme;
- the second application would be based on the satellite vehicle positioning technology (VPS-ETC) and would aim to cover all the vehicle-*kilometres* travelled within the zone covered by the scheme.

2.2 The conditions for implementing an emissions permit market

On the basis of experience of emissions permit markets and summaries that have been conducted elsewhere (cf. OECD 1997 1998) the main criteria for the success of such systems can be listed (see Box 1). These criteria will serve as a reference for the design and appraisal of the proposal which will be made below.

In order to design an emissions permit market, a series of questions, briefly set out below, must be answered.

The first relates to the specification of the unit to be traded. In view of the stated objectives, this will consist of driving rights (DR). It must be possible to make distinctions with regard to these driving rights on the basis of space and time (congestion) and according to the vehicle's emissions levels (pollution). The mechanism for doing this and its parameters must then be specified.

The second question relates to specifying the entities which will hold and trade quotas and be obliged to return them on the basis of their emissions. This can consist of motorists or inhabitants.

Box 1
The criteria for the success of tradable emissions permits

1. Broad agreement is required on the need to act and the effectiveness of the system with regard to improving the environment and its lower costs in comparison to other systems or solutions.
2. The system must be simple and clear: it is necessary to draw up simple rules, create market boundaries and a specified measurable and verifiable unit of exchange and clearly identify participants.
3. The participants must be able to afford the foreseeable price of the permit in practice.
4. There must be a sufficient number of participants for the market to function.
5. Marginal depollution costs must differ sufficiently for gains to be made as a result of trading.
6. Transaction costs must be limited.
7. Tracking, checks and penalties must have credibility.

8. Certainty is necessary with regard to the mechanisms for allocating permits and their validity in the future.
9. The system must take account of equity and, more generally, social and political acceptability: the introduction of new pricing instruments is usually perceived as inequitable, so these aspects must be included from the outset with any corrective compensation measures that are necessary.

The third question is how these quotas will be allocated. Should they be allocated free of charge? If not, the entities affected by the scheme will have to buy all the permits they need on the market: in the event of the total available quantity on the market being small, it is equivalent to setting up a quota auction. Economically, this is the most efficient solution as it obliges actors to reveal their preferences. It is also consistent with the polluter-pays principle and creates a usable financial resource. However, as with congestion charging it immediately increases the financial burden on the actors involved: this would eliminate the essential acceptability advantage that driving rights could have over congestion charging. Consequently, at least some of the quotas would have to be allocated free of charge as a visible and immediate compensation in order to facilitate this instrument’s acceptability.

If the quotas are allocated free of charge, to whom should they be allocated and with what distribution method? The problem is that although in theory these methods do not threaten the effectiveness of the instrument, they ultimately determine the financial burden on the participating entities. Will these entities be vehicle owners or inhabitants? Choosing the latter would amount to compensating inhabitants for the consequences of congestion and pollution. This would involve those who travel little, pedestrians and public transport users and not only motorists, which would improve the acceptability of the scheme.

Other issues relate to the period of validity of the quotas and the quota payment obligations. These parameters must be fixed in a way that maintains incentives to reduce consumption of driving rights, particularly during congested periods, and to reduce pollutant emissions.

The principal characteristics of the operation of the permit market must also be specified, that is to say how the transactions will take place, how much flexibility will be allowed to individual holders who trade rights, what role, if any, could be granted to financial intermediaries other than the regulating authority.

Last, two questions must receive particular attention. The first is the possibility of keeping the transactions anonymous, which is an obvious factor for the acceptability of a new control mechanism. The second is how to deal with “border effects”, in particular the management of occasional users and the anticipation of unforeseen behaviours which might undermine the effectiveness of the programme.

These points are covered in the following proposal.

3 A system of tradable driving rights for urban areas

From the previous specifications, detailed aspects are now discussed. Firstly the unit to be traded is defined with the computation of driving rights according to congestion and pollution levels, followed by the issue of total quantity to allocate for free. Then successively aspects of market and quotas trading, period of validity of quotas, tracking and checks of driving rights consumption and finally the compatibility with other regulations, are analysed.

3.1 The unit to be traded

The unit to be traded would be the driving right (DR). In the RS-ETC system, the unit of account for DRs would be the trip, but in the VPS-ETC system the unit of account for DRs would be the VKT. The users would therefore pay a total number of DRs, i.e. either trips or vehicle-kilometres of travel.

An agency in charge of transportation in the conurbation and receiving its powers from the local elected authorities would fix the parameters of the programme. To do this, the agency would make use of a survey system including, for example, Household Travel Surveys and traffic count data (for example from cordon traffic surveys).

The agency would specify the zones (on the basis of population density), the peak and off-peak periods, as well as the vehicle emission classes (using, for example, the Euro standards). These parameters would be used to compute the weighting of the DRs which would be charged to drivers. The DRs would be weighted on the basis of the level of congestion, which provides an indication of excess pollutant emissions, but also on the basis of the size of the vehicle in passenger car units (PCUs) and its atmospheric pollutant emission class.

All the vehicles entering and travelling within the zone covered by the scheme would be liable to return DR quotas to the agency on the basis of a computation method as described below.

M1 petrol car	Euro I	10	Zone with low population density	1
	Euro II	5	Zone with high population density	2
	Euro III	2		
	Euro IV	1	Off-peak period	1
VP Diesel M1	Euro I	10	Peak period	2
	Euro II	9		
	Euro III	5		
	Euro IV	3		

Table 3: Weighting factors for driving rights

Table 3 sets out some weightings which could be applied. With respect to pollutants, beginning with the vehicle that pollutes the least (the Euro IV M1 petrol passenger car) and on the basis of HC + NOx emissions, the multiplication factor can be deduced from the data in Table 1, i.e. between 1 and 10.

It is also possible to establish a weighting factor for congestion, making a distinction between the zone of travel (low/high density) and the time of travel (off peak periods / peak periods) as a result of the increase in the level of congestion in these zones and the larger population that is exposed to nuisance in them.

For example, a Euro IV petrol vehicle would use DRs at a rate of 1 DR per trip (or VKT) during an off peak period and in a sparsely populated zone. In the case of a Euro IV diesel vehicle, three times more DRs than this would be used. The same Euro IV diesel vehicle would have to pay in all 12 times more DRs during a peak period and in a dense zone. Still taking as a reference the Euro IV petrol vehicle travelling in an off-peak period and a sparsely populated zone, the multiplying factor would increase to 40 for a Euro 1 vehicle travelling in a peak period in a densely populated zone. This may seem excessive, but these weighting coefficients have only been given as an example. Weightings must be adjusted precisely on the basis of the estimated costs of congestion and pollution.

These weightings obviously assume the capacity to differentiate between vehicles actual use on the basis of their Euro category (see “Tracking and Checking” below).

3.2 Allocation

The proportion of the DRs allocated to the inhabitants of the urban zone would be estimated initially by the survey system described above. These DRs would be distributed free of charge equally between all the inhabitants. There would be no need to certify this estimate as being precise (indeed, from a statistical standpoint, this would be impossible), it would merely serve as a basis for the elected representatives to decide what they think it is fair to allocate free of charge to inhabitants. Each inhabitant would have a DR account with the agency, and this account would initially be credited with this free allocation.

The DRs which are not allocated would be sold by the agency. This means those motorists who live outside the conurbation and business users (for example, those making deliveries for firms, tradesmen, doctors, etc), those making through trips, and those inhabitants of the urban zone who have used up their remaining DRs would be able to purchase DRs. The sale of these rights by the agency would resemble conventional congestion charging.

The agency would vary the total number of DRs allocated and sold over time: this total could be maintained constant if priority were given to limiting traffic, or it could be increased if the economic development of the conurbation so required. In this connection, the level of demand for the rights that are put on sale would provide a good indicator of user preferences and the need to increase transport supply.

As DRs are allocated to individuals but used by vehicles, there is an obvious incentive for carpooling.

3.3 The market and quota trading

The trading of rights can take two possible forms:

- The more ambitious option would consist of a full market, those rights which are not allocated freely being auctioned. Financial intermediaries (banks) could be involved in trading and then offer rights to their clients. These auctions would produce an equilibrium price at which private individuals holding unused rights could sell them. For safety purposes, in order to avoid an excessive rise in the event of an error when evaluating the total number of rights to be put on sale, the agency would fix a maximum price for rights at which it would sell them.
- The less ambitious option would try not to leave the management of driving rights entirely to the market: rights which are not allocated free of charge would be sold at a price fixed by the agency and at which the agency would buy back unused rights.

However, nothing would prevent a holder of unused rights from transferring them (or even giving them free of charge) to an acquaintance. In practical terms, this would involve simply notifying the agency that rights have been transferred from one account to another (for example by making an electronic transfer on the Internet). Obviously, there would be no black market as sale and purchase would be unrestricted.

Likewise, small business users would be able to use the rights allocated to them as residents of a conurbation for either their private or their business trips. Last, it might be possible for families to combine the rights accounts of their members to form a joint account to which the DR smartcards of all the motorists in the family would be linked.

3.4 Period of validity

At the start of the scheme, each resident in the urban zone would have a free allocation which is equivalent to several weeks of rights quotas, so that from the outset they would each be able to use the rights they are allocated variably from one week to another. Next, at the start of each week, the resident would be allocated rights quotas for a period of seven days, thus giving the rights holder the flexibility to distribute them over the week as he/she wishes from the outset. These rights would be valid for one year after they have been allocated. Unused rights could be sold back to the agency at any time, even after their validity has expired.

The balance of a resident's DR account should never be negative. Put another way, as soon as a resident's rights have been completely used up, he or she would have to buy the necessary additional rights at the market price.

The risk of over-consumption of rights at certain periods during the day, the week or the month would be quite limited for a number of reasons. First, the rate at which DRs are used up increases with the level of congestion and pollution: there would be an opportunity cost for each right, those used up during a congested period will not be used elsewhere or at another time. Next, using these rights would be associated with another (transport) expenditure to perform an activity whose net utility would have to be positive in order for it to take place. Last, as the agency would be able to buy back unused rights, residents would have no incentive to make additional trips to use up their rights.

3.5 Tracking, checks

The DR collection system would be as described below, either taking the form of RS-ETC or VPS-ETC.

The electronic smart tags would be provided free of charge to motorists in order to encourage electronic transactions as much as possible, thus easing traffic flow through the checkpoints. This equipment would identify a type of vehicle and, in particular, its Euro class. It would permit the automatic debiting of the required number of DRs from a smartcard while vehicles are travelling.

The DR smartcards would be distributed free of charge to those who choose to have the on-board equipment. The cards would be credited with the DRs allocated to or purchased by the motorist.

In the RS-ETC system, the number of vehicle detection gantries should be minimised by using natural barriers (for example, rivers or railway lines) and the road network topology (i.e. single ways).

In order to improve the acceptability of the scheme, a maximum daily number of DRs to be debited would be set, following the example of the maximum daily charge in the Stockholm congestion charging trial.

Coping with occasional users. This is the Achille's heel of electronic toll collection systems. With the RS-ETC system potential malfunctions or violations must be detected with the help of video enforcement systems (VES) as previously quoted. The VES can be used to detect vehicles non equipped with on-board equipment either because they only drive occasionally in the zone (for example, visitors) or because they refuse to have on-board equipment of any type. This was the policy of the Stockholm congestion charging trial. While having being detected, the driver can pay the charge after his/her driving within a given period (for instance 2 weeks as in the Stockholm case). The payment and recovery mechanism for the invoice could be similar to that in the London or Stockholm scheme (unsolicited payment by Internet, telephone or in shops before a potential fine and recovery by a specialized firm).

In order to minimise the amount of such potential a financial incentive can be offered to register and get the on-board equipment. This incentive could be that the regular fee for driving through the scheme area for one day while not being registered would be the equivalent of the maximum daily number of DRs debited applicable to registered users (see above).

In the near future, a generalisation of interoperable on-board equipment is to be expected on vehicles, such as the Norway-originated Autopass system which is extending to other Scandinavian countries. That is to say a vehicle having contracted with an operator of an urban area would be recognised in another urban area. Information about the vehicle's Euro class could be retrieved on the basis of it registration number. It is possible that in the near future all vehicles will be fitted with tamperproof RFID tags containing all this information, as this has already been proposed as an anti-car theft measure.

However, in the VPS-ETC with a satellite-based vehicle positioning system, the management of occasional users would be more difficult, as it would require either the satellite tracking system to be duplicated by roadside gantries or manual checks. The resulting possibility of fraud or at least evasion could be seen as unfair by users with vehicles equipped with an OBU. A VPS-ETC system is only of interest if in the future all the vehicles are equipped with positioning systems which would be capable of interacting with the road pricing system. This would require technical harmonisation of the ETC systems in all urban areas and for the entire vehicle fleet.

Finally, it should be stressed that the privacy concern is adequately addressed with an RS-ETC system such as the one used in Singapore (see above). This is not yet the case with VPS-ETC.

3.6 Compatibility with existing or future regulations

What is proposed would be an additional system and there would be no redundancy with a tradable fuel permit system (see above) which would not be restricted to urban zones. The objective of this system is in fact different as it aims to limit CO_2 emissions which are directly proportional to the consumption of fossil fuel.

TDRs would, of course, replace conventional congestion charging. Existing parking control systems could, however, be maintained.

4 An example of implementation

We give an overview of a proposed scheme that would be implemented in the Lyon urban area. This scheme is then assessed with computation of various economic surpluses.

4.1 Practical implementation

The Lyon conurbation (1,200,000 inhabitants) has a typical European urban form in which the central zones contain approximately half the inhabitants and jobs with an average population density of 9,000 inhabitants per km². However, like similar agglomerations Lyon is subject to urban sprawl, with both population and jobs having a long term tendency to move into the suburbs and the outskirts.

The implementation of DRs would be based in a first step on an RS-ETC system as described above which would regulate the number of trips. For the sake of simplicity in the first years of the scheme no particular weighting would be applied to DRs according to Euro standard or to peak / off-peak period of driving. However the detection and debiting of DRs would be effective only in periods of higher traffic, for instance between 6h and 19h from Monday to Friday: this would be a proxy for weighting DRs according to congestion.

The main difficulty is then to detect car "trips"[6] since traffic would be monitored only by detection of vehicles when passing a gantry. The solution would be to define the "trip" as the period of one hour of car use[7] after the first detection by a gantry. That is to say, if the car is detected again within this period of one hour, it would be considered as the same trip and no supplementary DR would be debited. Trips of more than one hour duration would be longer distance trip and then it would be fair to debit one more DR.

Table 4 gives daily average number of trips for all individuals and workers (inhabitants of the Lyon area), and a distinction with the level of income,[8] according to data from the 1995 Household Travel Survey in Lyon.

	All individuals (5 and over)				Workers			
	%	as a driver	as a passenger	total	%	as a driver	as a passenger	total
Low income	35.2	1.13	0.44	1.57	24.2	2.35	0.27	2.62
Medium income	31.8	1.68	0.48	2.16	34.7	2.65	0.29	2.93
High income	33.1	2.13	0.53	2.66	41.1	3.03	0.30	3.33
Total	100	1.63	0.48	2.12	100	2.73	0.29	3.02

Source: Household Travel Survey, Lyon (1995)

Table 4: Daily average number of trips by car (HTS Lyon 1995)

[6] The option of driving *days* rights is dismissed because it is not sufficiently linked to travel intensity and period.

[7] This period of one hour looks sufficient given the current traffic conditions in Lyon.

[8] This is an income per adult equivalent unit, in order to take into account differences in size and structure between households. Low income stand for income less than 886 € per month, medium income between 886 and 1344 €, high income beyond 1344 € (see Nicolas and al. 2003).

In order to avoid too much harmful immediate effect on car mobility when it is used to reach one's workplace, the free allocation of driving rights would for instance initially amount to 3 DRs (i.e. 3 trips) per working day. According to this allocation, as shown in Table 4 on average low income workers would have rights to sell, medium income workers would be neutral, while high income workers would have to buy additional rights if they want to maintain their level of car mobility for work purposes. Such data show that the scheme would be progressive in relation with income level.

This kind of initial allocation would from the start of the scheme initiate a market between those who would have to buy additional rights and those who would sell unused rights, even if the total allocation would be large enough to cope with current total car trips. This initial allocation would improve the acceptability of the first years scheme implementation. However, after this first period, the agency in charge of allocation of DRs would announce a step-by-step decrease of the individual free allocation each year.

When the VPS-ETC is feasible and affordable then the trip DR scheme would be replaced by a distance DR scheme.

4.2 Assessment

Assessment method. Our appraisal is based on the use of a strategic travel demand model developed for the Lyon conurbation in 1997. This model has a conventional architecture consisting of five submodels (Raux 2002b). These are: 1) zonal trip generation, estimated on the basis of socio-demographic and economic trends; 2) the spatial distribution of trip origins and destinations, based on a gravity model whose deterrence function varies according to the generalized cost of inter-zonal trips; 3) interzonal modal choice, which estimates the proportion of trips that use walking or bike and then distributes the motorized modes between public transport and the private car using an aggregate logit procedure; 4) transformation of the daily origin-destination matrices into peak period matrices by applying factors based on past observations; the four above submodels have been calibrated and operate in parallel for four types of trip purpose – work, shopping and services, education and other purposes. The last submodel (5) uses an iterative procedure to allocate the trips for all purposes to the different routes, and places them in competition with each other, and also with through and inbound / outbound traffic.

The model was calibrated on the basis of three household surveys (1976, 1986, 1995), which were conducted during a period when travel costs, particularly for private cars, were continually falling either because of an improvement in roads or a reduction in the price of fuel relative to purchasing power. This has resulted in greater travel distances which are integrated within the model by means of the origin and destination spatial distribution submodel.

However, introducing area road pricing or tradable driving rights into the agglomeration would break this trend with numerous impacts: changes in route in the case of different tolls for different routes, changes in trip times in response to peak period pricing, changes in travel mode, changes in destination when trip purposes allow it, and medium- and long-term effects on the location of activities (jobs, shops, services, housing). The last changes would result ultimately in other changes in trip destinations. The net direction and magnitude of these last effects are difficult to estimate, and this uncertainty reflects our limited current knowledge about the interactions between the conditions of transport and urbanization. For this reason, assessment has been limited to a short-term horizon.

In order to effectively isolate these short-term effects, we decided to freeze the socio-economic situation (population, jobs and their locations, income, etc.) and the spatial distribution of trips (origins and destinations) in 1995, the model's base year. Consequently, only two out of five submodels are "active", the modal choice model[9] and the route assignment model[10]: a deterioration in the conditions of travel by private car can lead to a transfer to other modes or a change of route, and vice-versa. Lastly, the model computes the travel conditions on the road network during the morning peak hour (7-8 a.m. in 1995). In brief, the trip volumes for each origin-destination pair remain constant, all that changes is the modal choice and the route taken between zones.

The assessment of DRs scenarios will be performed with reference with a conventional road pricing alternative. Figure 1 shows a convenient approximation of the demand curve (or willingness to pay), that is to say change in demanded quantities (vehicle trips, on the x-axis of this graph) as a function of the price (on the y-axis). The current price (P_0) corresponds to the average generalised cost already borne by the driver (monetary cost of using the car plus time spent in travelling). To this is added the congestion fee or the price of the permit, represented by *t*, yielding the price P_1.

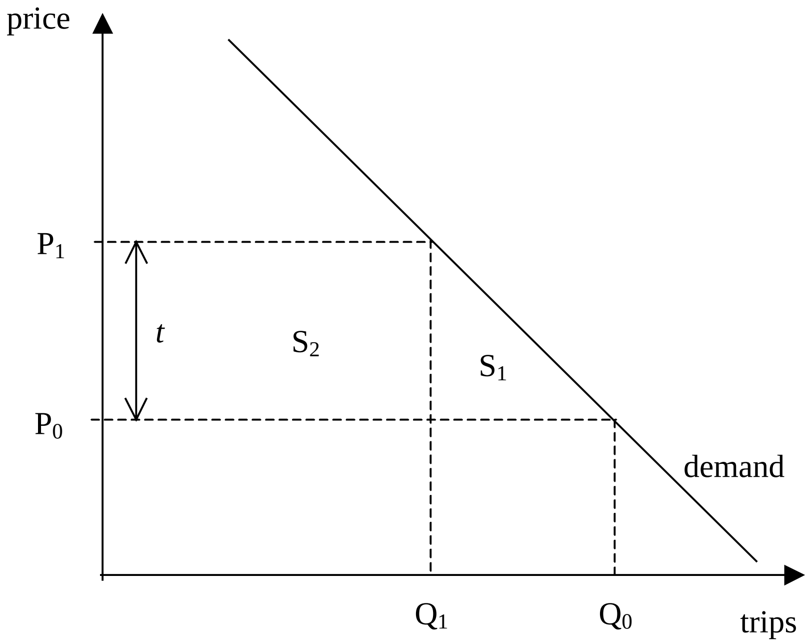

Figure 1: The effects of congestion pricing or tradable driving rights on travel demand

The transition from a price P_0 to a price P_1 will result in a modification of behaviours, which will in turn reduce car trips demand, from Q_0 to Q_1. The resulting surpluses will be as follows:

[9] For the trips made by residents of the conurbation.

[10] For the trips made by both residents of the conurbation, and through and inbound / outbound traffic.

- S_1 represents the loss in consumer surplus resulting, for example, from the reduction of car trip-making or the purchase of a less polluting but more expensive car: this loss is net of the cost previously supported $(Q_0\text{-}Q_1).P_0$.
- S_2 represents, in the case of congestion pricing, the gain in local government's surplus that results from the newly congestion fee paid by the drivers, i.e. $(Q_1.t)$. S_2 is a loss for drivers.[11] In the case of permits, local government is no longer involved and S_2 represents, for holders of permits, the gains that result from the sale of permits or the losses that result from the purchase of permits.

The surplus for drivers is (S_1+S_2). The surplus for local government is (S_2) when the congestion fee is applied. In addition, as we are only comparing congestion pricing with tradable driving rights, we take no account of the gains in congestion, accidents, local pollution and noise which would result from a reduction in traffic, as these gains are similar in both cases. Moreover in our exercise the overall surplus change is the same when comparing congestion pricing and permits. The differences between the two instruments lie in the distributions of surplus between categories of motorists and between motorists and the local government.

Results. An assessment of road pricing scenarios was conducted in a previous study on the Lyon conurbation using observation data from 1995 (Raux and Andan 2002). These scenarios assume that, by using appropriate electronic toll technology (for example the RS-ETC system described above), it would be possible to distinguish the vehicles belonging to residents of the conurbation from those of non-residents. The first group would pay an area pricing in the form of a fixed daily payment covering all trips and the second would be subjected to a first cordon toll when entering the conurbation and a second cordon toll when entering the central zone. The scenario which most reduces the total traffic in the conurbation (a 5% reduction in the 2.6 million daily vehicle trips of which 8% are made by vehicles from outside the conurbation), is that in which the area pricing for residents' vehicles is €3 per day and the toll for entering either of the two cordons is also €3 per day.

If motorists pay an average charge of €0.75 per trip (individuals make an average of 4 private car trips per day), we can deduce that the loss in surplus for drivers S1 is approximately €10 million per year. The surplus S2, i.e. the revenue from the 95% of trips that continue to be made, would then be €370 million per year.

With the implementation of TDRs, if it is assumed that the quantitative objective is to reduce traffic by 5% in relation to the current situation, the loss in surplus for drivers S1 would be unchanged in relation to the situation with a toll.

However, in the case of TDRs most of the surplus S2 would be redistributed between motorists instead of becoming revenue for the transport authority. A small proportion of this surplus, corresponding to the 8% of external traffic without a free allocation of TDRs, would constitute revenue for the transport authority, amounting to €28 million. If all of the TDRs were allocated freely, €342 million would be spent on DRs or transferred between motorists wishing to travel by car within the conurbation.

[11] (S_1+S_2) is of course offset by the suppression of the deadweight loss previously due to congestion.

5 Barriers to implementation and how to overcome them

Barriers to the implementation of TDR are mostly the same as for conventional urban road pricing as the purpose of both instruments is to regulate transport externalities and hence travel intensity. These barriers have already been identified in the literature (see Jones, 1998; Schlag and Teubel, 1997). Firstly the opinion must agree for the need for action and that depends on the level of concern for congestion or for environmental degradation originating from transport activity. The opinion must also be convinced that alternative solutions such as public transport improvements, park and ride schemes or policy encouraging alternative travel by bikes or walking, are not sufficient when congestion or pollution are reaching too high levels. Besides this indicates that TDR like urban road pricing is not a panacea that should be implemented in all urban areas. Building a broad agreement for action and "radical" policy needs communication and debates.

The technical or practical feasibility of regulating vehicles with TDR has been addressed previously when analysing the already implemented electronic road pricing in Singapore. There is however a risk that economic feasibility could be undermined by an excessive cost of implementation and operation (see for instance the controversy about the net surplus of London congestion charging scheme due to the high cost of monitoring and collecting revenues: Prud'homme and Bocarejo, 2005; Raux, 2005). Here again figures quoted above regarding the Singapore implementation of ERP indicate that costs can be made moderate.

The issue of legal feasibility of regulating urban car travel with TDR is broadly analogous to the one for area or cordon road pricing. The national legal framework must be made compatible if needed, which is not yet achieved in many countries including France.

One of the main barrier to implementation of regulation appealing to the market is equity concerns, summarised as "the poor won't be able to travel any more". At this point there is a noticeable difference between TDR and road pricing, since part of the TDR can be allocated for free: this is a guarantee for a minimal travel capability which is not affected by the pricing of rights on the market, even for the drivers not willing or being able to abandon their car. Regarding acceptability this free allocation is an advantage for TDR upon road pricing.

Geographical equity is also a crucial issue when drivers living inside the charging zone get discount fees like in London congestion charging scheme, or travel for free if they stay inside the cordon like in Oslo or Stockholm. In these two latter cases this issue has been resolved by agreements between local governments of the charging and surrounding areas about the allocation of revenues from pricing. A similar agreement must be reached in the case of TDR since rights would be allocated for free to the inhabitants of the regulated zone and revenues would come from rights purchased by drivers living outside the regulated zone.

Conclusion

It has been shown that driving rights markets have three advantages over urban road pricing schemes which make them particularly appropriate for limiting congestion and the pollution caused by urban traffic. The first advantage is the guarantee that a predefined quantitative objective will be attained, whether this involves limiting congestion in the short term or not exceeding certain atmospheric pollution thresholds. The second advantage is that it separates issues of allocative efficiency from issues of equity: the possibility of maintaining a part of travel “free” besides the part that is subject to a charge is an obvious factor that makes it more acceptable than conventional urban road pricing. The third advantage is that with this free allocation, individuals have a supplementary incentive to save whether trips or distance travelled by car, beyond their initial allocation of driving rights because they can sell unused rights and then get tangible reward for their “virtuous” behaviour.

More generally, the allocation of TDRs creates a kind of rights on the urban rent which are shared among the inhabitants rather than being captured by the local government. These characteristics make TDRs essentially different from conventional urban road pricing even with special discounts for some users.

Analysis of potential applications for managing urban travel demand has revealed two priority targets: the first is trips or VKT, in order to control congestion; the second is the same target modulated on the basis of the pollutant emission categories of vehicles in order to control atmospheric pollution.

The assessment of ETC technologies has shown that one of them, that combines on-board and roadside equipment, is proven by effective implementation with acceptable cost in several cities. Another technology which may be considered, but more for the future, is based on the combination of a universally installed satellite-based vehicle positioning system and a toll collection system.

Based on these technologies and objectives with regard to limiting congestion and the environmental harm caused by urban traffic, the design of a system of tradable driving rights is possible. Quite a detailed design has been performed, which includes border effects such as the processing of occasional users, that makes it reasonable to envisage its application in an urban agglomeration.

Conventional congestion charging involves a transfer from motorists to the community, which is able to use the revenue as it judges best, while the free allocation of tradable driving rights confines a certain proportion of the transfers to within the group of motorists and population. This loss of revenue for the public authorities represents the price that must be paid for the acceptability of congestion charging, and this price may seem very high.

A possible strategy would be to introduce a traffic capping mechanism and keep this quantitative level constant from year to year. As demand increases with the growth of the agglomeration, purchases of the additional TDRs which are required would provide revenue for the transport authority. Thus transport users would reveal their preferences, providing a signal to the community to invest in a cost-efficient manner in developing the supply of transport, but not necessarily road transport.

Acknowledgements

I acknowledge useful comments by Bruno Faivre d’Arcier on an earlier version of this paper. I also wish to thank Pascal Pochet for computing statistics on the Lyon Household Travel Survey.

References

Albrecht, J. (2000), The diffusion of cleaner vehicles in CO_2 emission trading designs. *Transportation Research Part D*, 5:385-401.

Baumol, W., Oates, W. (1988), *The theory of environmental policy*. Cambridge University Press, Cambridge, 299p.

Chin, A. and Smith, P. (1997), Automobile Ownership and Government Policy: The Economics of Singapore’s Vehicle Quota Scheme. *Transportation Research Part A* 31: 129-140.

Coase, R. (1960), The problem of Social Cost. *Journal of Law and Economics*, 3: 1-44.

Daganzo, C.F. (1995), A Pareto Optimum Congestion Reduction Scheme. *Transportation Research B*, 29:139-154.

Dales, J.H. (1968), Land, water and ownership. *Canadian Journal of Economics*, 1: 797-804.

Foster, V. and Hahn, R. (1995), Designing more efficient markets: lessons from Los Angeles Smog Control. *Journal of Law and Economics*, 38:19-48.

Godard, O. (2000), L’expérience américaine des permis négociables. *Économie Internationale* 82: 13-43.

Goodwin, P.B. (1988), *Evidence on car and public transport demand elasticities 1980-1988*, TSU Ref 427, Oxford, June 1988.

Hahn, R. and Hester, G. (1989), Marketable permits: lessons for theory and practice. *Ecology Law Quarterly*, 16:361-406.

Hau, T.D. (1992), *Economic fundamentals of road pricing : a diagrammatic analysis*. The World Bank, Policy Research Working Paper Series, n°1070, 96p., December 1992

Hugrel, C., Joumard, R. (2006), *Directives et facteurs agrégés d’émission des véhicules routiers en France de 1970 à 2025*. Rapport LTE n°0611, Juin 2006. INRETS, 160 p.

Kockelman, K.M., Kalmanje, S. (2005), Credit-Based Congestion Pricing: A Proposed Policy and the Public's Response. *Transportation Research 39A*: 671-690 (2005).

Koh, W.T.H. and Lee, D.C.K. (1994), The vehicle quota system in Singapore: an assessment. *Transportation Research Part A* 28: 31-47.

Marlot, G. (1998), Réguler la congestion par des permis négociables: une solution au dilemme efficacité / acceptabilité. 8th WCTR, Antwerp.

Menon, A.P.G. (2000), ERP in Singapore – a perspective one year on. *TEC* February 2000.

Menon, A.P.G., Chin, K.K. (2004), ERP in Singapore – what’s been learnt from five years operation? *TEC* February 2004.

Montgomery, W.D. (1972), Markets and licenses and efficient pollution control programs. *Journal of Economic Theory*, 5: 395-418.

Nakamura, K. and Kockelman, K.M. (2002), Congestion pricing and road space rationing: an application to the San Francisco Bay Bridge corridor. *Transportation Research Part A*, 36: 403-417.

Nicolas, J.-P., Pochet, P., Poimboeuf H. (2003), Towards sustainable mobility indicators: application to the Lyons conurbation. *Transport Policy* 10 (2003) 197-208.

OECD (1997), *Putting Markets to Work. The Design and Use of Marketable Permits and Obligations*. Organisation for Economic Cooperation and Development, Public Management Occasional Paper 19, Paris.

OECD (1998), *Lessons from Existing Trading Systems for International Greenhouse Gas Emissions Trading*. Organisation for Economic Cooperation and Development, Environment Directorate. Paris.

OECD (2001), *Domestic Transferable Permits for Environmental Management. Design and Implementation*. Organisation for Economic Cooperation and Development, Paris.

Ottensmann, J.R. (1998), Market-based exchanges of rights within a system of performance zoning. *Planning and Markets*, 1.

Pigou, A.C. (1920), *The Economics of Welfare*, MacMillan, Londres.

Prud´homme, R., Bocarejo, J.-P. (2005) The London Congestion Charge: a tentative economic appraisal, *Transport Policy* 12 (2005) 279-287.

Raux (C.) (2002b), Uncertainties in Forecasting: The Role of Strategic Modeling to Control Them. In H.-S. MAHMASSANI (ed), *In Perpetual Motion. Travel Behavior Research Opportunities and Application Challenges*. Pergamon, Elsevier Science, Oxford, 2002, pp. 505-526.

Raux, C. (2002a), The Use of Transferable Permits in the Transport Sector. In OECD (ed), *Implementing Domestic Tradable Permits. Recent Developments and Future Challenges*. OECD Proceedings, Paris, 2002, pp. 141-185.

Raux, C. (2004), The use of transferable permits in transport policy. *Transportation Research Part D*. Vol 9/3, pp 185-197.

Raux, C. (2005) Comments on “The London congestion charge: a tentative economic appraisal” (Prud’homme and Bocarejo, 2005). *Transport Policy*, 12 (2005) 368-371.

Raux, C., Andan, O. (2002), Comment les péages urbains peuvent-ils satisfaire une politique d’agglomération ? *Recherche Transports Sécurité* 75 (2002) 115-130.

Raux, C., Marlot, G. (2005), A System of Tradable CO_2 Permits Applied to Fuel Consumption by Motorists. *Transport Policy*, 12 (2005) 255-265.

Stavins, R. (1995), Transaction costs and tradable permits. *Journal of Environmental Economics and Management*, 29:133-148.

Verhoef, E., Nijkamp, P. and Rietveld, P. (1997), Tradable permits: their potential in the regulation of road transport externalities. *Environment and Planning B: Planning and Design* 1997, vol 24, pp. 527-548.

Vickrey, W. (1963), Pricing in urban and suburban transport, *American Economic Review : Papers and Proceedings*, 53 (2), p.452-465, May.

Walters, A.A. (1961, The theory and measurement of private and social cost of highway congestion, *Econometrica*, vol 29, n° 4.

Wang, M.Q. (1994), Cost savings of using a marketable permit system for regulating light duty vehicle emissions. *Transport Policy*, 1: 221-232.