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ROAD USE CONFLICTS: TOLLING STRATEGIES TO PRESERVE ACCESSIBILITY

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Abstract

It is not sufficient to state that road-user charging is the best instrument to address congestion situations in various locations and at various times. When facing practical implementation of road policies one should be aware of the diversity of categories of road users and of the corresponding accessibility objectives that may be pursued by public authorities, according to constraints of financing, environment and equity. Here are analysed the elements of a road tolling strategy offering the potentialities of adequate differentiation, according to exit and entrance points in the system, the routes in the network and the periods of road use. Finally the practical feasibility of such a strategy of demand management is shown on an example combining the access by corridors in an urban network of multiple bypass rings.

INTRODUCTION

There is a consensus to admit that it is not possible to expand road capacity in line with the growth in demand everywhere in the European Union. Scarcity of financial resources, worrying about pressure on environment and scarcity of space in dense areas are the main reasons to oppose a continuous expansion of roads and to search for a better management of the current infrastructure capacity or limit the need for additional infrastructure expansion (OECD/ECMT, 1995; EC, 1995). The most critical zones where road congestion occurs in Europe are those where meet each other on the one hand national and international traffics, concentrated in main corridors, on the other hand local urban traffics, developing with urban sprawl.

Road policies with tolls or regulations consist in favouring one kind of traffic against another. The first idea that we developed here is that there are as many groups of preferred road users as objectives defined by the transport authorities. This is not the subject here to prejudge the more or less essential characteristics of some group of users or other. The discussion will especially focus on the control methods which will enable us to identify the different groups of users and then to deal with them.

The purpose of this paper is to show how it is possible to reconcile an objective of fluidity and accessibility in transport system with constraints of financing, environment and equity.

It is impossible to consider priorities if we are not able to allocate them. So, it is necessary to design technical systems in order to pinpoint these different classes of users associated with these priorities: these kinds of systems can be based either on a regulation (access control according to the kind of vehicles, driving licenses or license plates, for example), which we will not further consider here, or on a fee (tolls, pay parking). Moreover conflicts between the different priorities take place in different spatial configurations (such as corridor, network, etc.): this requires more or less complex methods to differentiate road network users.

In the next section we will

- define the kinds of spatial configurations covering the different cases of space-time conflicts in road use,
- list the diversity of possible objectives pursued by the public authorities and the corresponding groups of users,
- recap the guidelines for an efficient travel demand management strategy essentially based on road user charging tools.

Then in the following section we will define the technical tolling systems allowing to distinguish and to deal with these different groups, i.e. allocate priorities, and appraise the appropriateness of these methods to the objectives pursued.

Finally this approach will be applied and tested on a complex case combining these spatial configurations of conflict.

SPATIAL CONFIGURATIONS OF CONFLICTS, TRANSPORT POLICY OBJECTIVES AND STRATEGIES

The implementation of transport policy objectives needs to consider first the spatial network configurations where conflicts for road use occur, second the diversity of transport policy objectives pursued by public authorities, and third the pricing principles compatible with these objectives.

Spatial configurations of road use conflicts

Three main kinds of spatial configurations of conflict for road use have been identified. Due to their potential combinations they represent most of possible cases to be noticed in the European context of urbanisation.

The first case of conflict concerns a corridor (Case 1), for instance motorway A7 in the Rhone Valley, between Lyon and Marseilles, close to saturation in some periods of the year, on some days of the week, at some hours of the day: in this case seasonal travellers add to local road users accessing to the conurbations located along this corridor and to regional exchange traffic in this region.

The second case concerns a congested corridor with an alternative route (Case 2): this is for example A6/A7 Paris-Lyon-Marseilles route versus A71/A75 route through Massif Central. Unlike the previous case, the existence of an alternative for long distance traffic provides an additional room of manoeuvre to adjust demand.

The third case is a corridor with an urban ring (Case 3a), in which the issue is to select between through traffics which must be encouraged to take the ring and local traffics of the conurbation which must be treated differently. This case can be made more complex with an urban sprawl made up of several areas of different densities, for example city-centre and suburbs, which involves a differentiated treatment of the different kinds of flows internal to the city (Case 3b).

All these cases present a conflicting situation, on the one hand between a set of local uses, either exchanges inside an urban area or in a multi-polar urban region, and on the other hand a set of longer distance traffics. For instance the case of a network mixing congested and non-congested links, as in Randstad or in Ruhr, or Cologne or Rhein-Main area, can easily be derived from case 1 and 2 and 3.

From multiple objectives to users categories

Four kinds of objectives can be distinguished such as:

- the European cohesion concern and the associated necessity to preserve the right to mobility for the long distance through traffic, freight or tourism;
- the necessity of inserting cities and their area of influence (urban region) into a national and an European framework;
- the same necessity of regional insertion for the city, which implies that its exchange capacities with its catchment area must be preserved;
- the problem of urban functioning, which implies that accessibility to local urban functions for different purposes between the different urban areas must be also preserved.

For each of these objectives, groups of road users can be defined, according to their travel purposes (delivery, business, leisure, work commuting, shopping), to their main travel period (peak, off-peak) and to their origins and destinations (through traffic, exchange, local) relatively to a given urban area.

At last, these objectives have to be pursued given at least three constraints:

- a financial one because of the scarcity of public resources for extending both road capacity and public transport supply;
- an environmental one due to higher concerns regarding local and global pollution coming from transport activity and more generally nuisance on the environment (noise, insecurity...);

- a spatial equity one: the concern with solidarity, questioned by a spatial segregation of the social groups within an agglomeration, implies to remain vigilant as for the equity of access to the transport systems and the various areas of the agglomeration.

Which strategy is compatible with these constraints?

The theoretical bases of road pricing were posed essentially more than a century ago with work of J. Dupuit (1844, 1849) on the one hand and of A.C. Pigou (1920) and F.H. Knight (1924) on the other hand (see also Goodwin and Jones, 1989). As the congestion is a phenomenon which appears in variable places and at variable times, the obvious instrument is road user charging by means of toll, technically better able to reflect the variations of costs and to manage the discrepancy between demand and supply.

For some economists the congestion could be easily solved by privatisation of roads and by letting competition fully play. However alternative routes are not perfectly substitutable and situations of local monopolies would result from this. Moreover a mixture of private roads and public roads can have undesired synergistic effects in the case of networks in urban areas. It is clear that the public authority must intervene explicitly on the relative prices between the various routes and road sections, be they public or private.

As regards congestion pricing, it is known (Hau, 1992; Baumol and Oates, 1988) that its introduction makes it possible to improve the welfare of the society *as a whole,* but that redistribution takes place and particularly that drivers, either staying on the tolled road or excluded to non-tolled roads don't get advantages except those who have a high value of time. In the general case, there are thus few chances that the congestion pricing is accepted, except if the drivers consider that the public authorities will efficiently and fairly redistribute the collected resources, for example by a tax cut or the financing of new transport services (Goodwin, 1989; Small, 1992).

The profits generated using congestion pricing result in fact from the rents attached to land use and the impossibility of extension of surfaces available in urban area. This is why a logic of road investment driven by profits generated would lead to an overproduction of roads: it is thus important to realise a cost-benefit socio-economic evaluation for each project.

In addition, a control by congestion pricing would not be inevitably effective from the environmental point of view: the increasing valorisation of time in a society with market economy makes that the environment is likely to weigh less vis-a-vis the pressure of a solvent demand for time savings (Perl and Han, 1994). The optimal balance of the demand for automobile travel and thus of the consumption of environmental resources then seems the result of a race speed between three principal tendencies (Raux, 1996): they are the increasing preference for the environment, the improvement of the technical effectiveness of the road system and the valorisation of saved time. In this race, the two last tendencies and particularly the third appear up to now gaining. This explains why it is necessary to implement so high fees for congestion pricing to operate significant inflections of behaviours. As regards the attacks to safety and the environment, pricing is not the single means nor inevitably most effective and must be combined with regulatory measures.

Finally there is the concern with social and space equity. The space segregation resulting from the differentiation of land values within urban space, yields forms of captivity to such or such transport mode: financially constrained households going to live in periphery to find residences at low prices there, would be economically weakened by an increase in the costs of car use, in the absence of substitution alternative. That thus implies to work out transitional and compensatory measures at the time of implementation of a new pricing scheme.

In conclusion road user charging is a fundamental instrument in the management of the transport system. However the community must intervene so as to ensure the social optimum, or in terms of economic calculation, to maximise the collective surplus: the result will be a combination on the one hand of advantages (utility of travel) and costs (of use of the various modes and routes) for the users, on the other hand of advantages (toll receipts and taxes) and costs for the community (supply of transport alternative). That means that the optimal policies of transport will be different according to periods, locations as well as the trips considered: it is thus necessary to distinguish the various categories of road users in order to assign different priorities to them.

The technical solution of road pricing by means of toll thus does not define in oneself objectives. This consists in implementing priorities which necessarily rise from explicit or implicit objectives, as those previously described. How then can one technically identify or discriminate the users?

HOW CAN WE TECHNICALLY IMPLEMENT PRIORITIES?

Focusing on tolling systems, we define methods allowing to distinguish and deal with different road user groups. We first present technical systems: conventional open system, conventional closed system and hybrid systems. Then we evaluate the differentiating ability of these methods.

Principles of technical systems

Motorway toll systems (Eurotoll, 1996) can be categorised into two major groups, open and closed systems:

- in the conventional *closed* system, pricing is based on an origin/destination route: each entry and exit from the system is controlled; this system is heavier to manage and more appropriate for long distances;
- in the conventional *open* system, pricing is on an elementary section basis: all the flows using one section are controlled; this very simple system is appropriate to short routes but becomes penalising (with conventional techniques requiring vehicle stops) over long distances, unless electronic remote tolling systems be generalised.

Variations exist between these two basic categories: they are called "pseudo closed" systems and they allow pricing variation according to the route without incorporating the heavy management of the closed system. Pseudo-closed system can be achieved with additional control points upstream and downstream from a main section controlled under the open system.

The choice between open and closed systems depends on the technical possibilities and their associated costs on the one hand, on the comfort of use for the driver on the other hand. However from the point of view of the ability to distinguish categories of road users the two systems have important differences as we will see below.

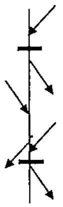
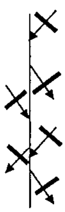
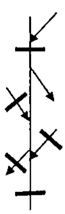
Compatibility with differentiation objectives

Within the objective of users differentiation, the open system is the most effective since it allows to address:

- the route taken by the user,
- the specific travel period on each section (time modulation).

The open system thus allows much more precise route and period targeting modulation than the closed system in a network. However the open system cannot control precisely the entries and exits in the motorway network (see Table 1).

Table 1: Technical systems, control possibilities and operation principles

		Vehicles identification	Comments
	open system	• OD unknown and uncontrollable, • but route and period of through traffic controllable.	• pricing on an elementary section basis, • appropriate to short distance trips, • appropriate to network route differentiation, • all the full way traffic is concerned: can't distinguish between long distance and short trips.
	closed system	• OD completely identified and controlled, • period of entry and exit controllable, • but period of long distance through traffic not controllable, route unknown on a network.	• pricing on an OD basis, • can be technically expensive if numerous entry-exits to control, • appropriate for long distance trips.
	pseudo-closed	• routes and period of through traffic partly controllable.	• combines the advantages of the two previous systems

The open tolling system can be used to modulate traffic in time in the case of a congested corridor. Nevertheless, this type of control is not able to discriminate between the local traffic and the through traffic. This implies important consequences if the modulation in time affects only some sections of the corridor, especially those concerned by local traffic, because it is in these sections that congestion is the most likely to occur. In this case, the overcharge implemented on these sections may have only little effect on the global cost for long distance traffic. The impact of the modulation in time would mainly penalise local traffic, priority being implicitly given to through traffic.

The closed system is the most relevant method to adjust the through traffic between two alternative routes (saturated corridor and alternative routes, case 2 of spatial configuration of conflict). But it becomes ineffective in a complete network when only entry and exit from the network are controlled, and the precise route taken by the driver not controllable. Moreover the closed system is unable to control the period of travel at certain locations in the network, as can be made with the open system.

This is why characteristics of both open and closed systems must be mixed, that is a combination of open system with entry or exit control, yielding a « pseudo-closed » system. For instance, an entrance control mixed with a system of full way control can be used in the case of a congested corridor to penalise local traffic and to give priority to through traffic, or the inverse when using a marker system for reimbursing local users. Conversely an exit control can be used in the case of a corridor to protect an environmentally sensitive area or an urban area: thus the priority can be granted to local traffic on the secondary network to the detriment of long distance traffic.

In brief these technical systems are able to differentiate road users according to:

- types of vehicles: light vehicle or heavy lorry;
- entrance or exit points of the system, which are approximations of the origins and destinations;
- routes in a network;
- periods of use of the road sections.

When confronted with the objectives described previously, the potential of these technical systems shows that it is of course not possible to discriminate the users directly according to travel purposes, but indirectly according to the characteristics shown above. However complementary differentiation schemes are possible, on the one hand by a preliminary identification of certain categories of users (e.g. local resident / non-residents) on the other hand by means of non-linear or binomial pricing.

AN EXAMPLE OF IMPLEMENTATION

After the presentation of the capabilities of tolling systems to differentiate between road users, a last stage consists in seeing on a concrete case if it is possible or not to support the functioning of an agglomeration with the three constraints of scarcity of the financial resources, of environmental concern and of space equity within the agglomeration. That means:

- for the scarcity of public financial resources, to set up a toll system suitable to finance any development of the transport system made necessary to manage the demand in an efficient way;
- for the environment, to reduce the nuisances related to transport and to respect daily life surroundings. This amounts to reducing the vehicle-kilometres travelled but also to making the traffic avoid the denser areas inside the conurbation;
- for space equity, to avoid any discriminating pricing between the local users, whatever their place of residence.

We propose to implement these various principles into a complex space configuration, combining access corridors to an urban area served by a network of several rings (cf. Figure 1).

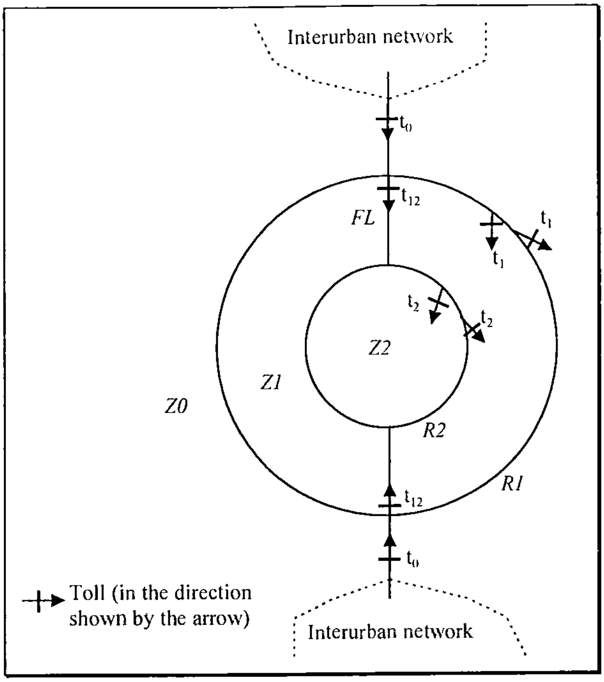


Figure 1: Corridor and network of bypass rings

It is a configuration which combines one or more corridors (only one is represented here to simplify) with two bypass rings connected by one or more fast links (FL). The internal bypass ring called R2 delimits the denser part of the agglomeration (zone Z2), while the external bypass ring R1 delimits the less dense part (zone Z1): most of employment is located inside this double bypass. In this configuration, the question is to select between the through traffics (which circulate between various points of Z0), those of exchanges (between on the one hand an origin in Z0, on the other hand a destination in Z1 or Z2, and conversely) and the local traffics (inside the areas Z1 and Z2), to be able to treat them differently. This problem of selection is of as much complex to solve as the two areas Z1 and Z2 are quite differently densely inhabited but must be treated in the same way, with reference to the space equity constraint: however they can imply a differentiated treatment, with reference to accessibility, insofar as zone 2 benefits from a quality of service in public transport quite higher than zone 1.

We suppose in addition that on this network of expressways is implemented an effective average speed from 80 to 100 km/h while on the secondary network (not represented here) an effective average speed of 50 km/h is implemented.

The design of tolling strategy supposes to have determined as a preliminary a certain number of principles making it possible to reconcile the aim of accessibility with the constraints, before discussing technical aspects making it possible to implement these principles.

Principles to implement

In the absence of complete economic calculation, which should be applied to a concrete case and which would carry out us beyond the scope of this paper, we suppose that the optimal policy consists in favouring at peak hours firstly the local traffic and then the exchange traffic and to simultaneously strengthening the public transport supply: the toll receipts are assigned to the financing of multimodal transport according to the program described previously (section 2). By which toll system can we operate a selection between the various road users within the objective to be reached?

We will start with the question of accessibility. This problem is particularly sensitive at peak hours when traffics of all kinds telescope. A guiding principle will be to try to distribute the kinds of traffics between the various routes. The direct access by the fast link (FL) must be reserved in theory firstly for the local traffic. The exchanges are treated as the through traffic insofar as the problem of their separation is difficult to solve. The exchanges and the through traffic must be encouraged to the maximum to take the bypasses, while being more and more severely taxed as they approach the downtown area.

A second question relates to the respect of the environmental constraints. It is advisable to protect to the maximum the areas of urbanisation Z1 and Z2 from a superfluous traffic. This principle of protection of the areas of urbanisation leads us to consider a double action.

The first action relates to the exchange and through traffics which one seeks again, but with reference to the environmental protection this time, to all the more strongly move away from these areas by more highly pricing them when they advance towards area Z2, particularly at peak hours.

The second action concerns the local users who should as much as possible be dissuaded to drive inside the dense areas in a double manner:

- at peak hours drivers have a higher price to pay insofar as they can benefit from a significant public transport alternative;
- at the same time local users whose origins and destinations are distant inside the urbanised area are encouraged to take if possible the bypasses rather than to drive through the dense areas.

A third question is to respect the principle of space equity for the local users. The principle adopted is that of the equalisation of the tariffs which are imposed to them, whatever their residence location in area Z1 or Z2.

Technical aspects of tolling

Once established these principles, another stage consists in setting up the technical means of implementing them. We will discuss in turn the case of the exchange and through traffics, then that of the local traffics.

The means which makes it possible to implement an increasing pricing as the exchange and through traffics approach the centre is to set up a system of exits control on the expressways:

- on the exit of the interurban network one implements a toll t_0 at entry to the network of expressways of the agglomeration;
- on the fast connection (FL) one sets up a full way toll t_{12};
- on bypass rings R1 and R2, the toll stations are located on all the exit points of the bypasses and make it possible to implement tolls t_1 and t_2 to all those which come out of these expressways whether inside or outside each bypass. These tolls concern traffic inside the dense areas and in proximity of these areas.

Once solved the case of the through and exchanges traffics, what does happen to the local users? These technical solutions are likely to penalise their use of the bypasses while at the same time this use is wished so that they avoid driving through the dense areas. This leads us to provide for a system of identification for the residents (sticker or electronic equipment). This identification gives them free access to the bypasses, the arbitrage between the various routes being done on the basis of authorised speed, either 30 to 50km/h on the internal roadway system in areas Z1 and Z2, or 80km/h and more on the expressways R1, R2 and FL.

Finally these tariffs can be modulated in time according to the risks of congestion to encourage with a traffic moderation. At least two and up to three levels of tariff are set up, while distinguishing peak hours, day off-peak hours and week end or night hours.

However to dissuade the residents to drive at peak hours, whichever the route taken, a right to drive in areas Z1 and Z2 is implemented. In order to obtain this right, it is necessary that they buy a daily pass (PR, resident pass) just like do it the non-residents when they penetrate downtown at these peak hours. With reference to the objective of supporting local traffic at peak hours, the residents benefit from the advantage of a more or less preferential tariff compared to the non-residents.

Operation of the toll system

The characteristics of the chosen system thus rise from these various options. We briefly point out them.

The level of pricing varies for the users according to four criteria:

- residence location: a resident tariff with free access to bypasses for those who live in dense area (areas Z1 and Z2) and a non-resident tariff for those who live outside (area Z0);
- utilisation frequency of the urban network: a pass (PR for the residents, t_{12}, t_2, t_1 or t_0 for the non-residents) either daily or subscription and which gives the right to drive on the chosen routes;
- frequented areas whose access pricing can be differentiated for the non-residents, for instance indicated by a coloured pass. For the residents, this type of differentiation does not exist insofar as resident pass (PR) is with the same tariff for all, in accordance with the constraint of space equity;
- period when the users circulate: peak hours, off-peak hours day or week end and night hours. At peak hours the tariffs are higher for all the users. At off-peak hours certain tariffs can become null: this is the case for t_1, t_2 and PR, while t_0 and t_{12} are fixed at a lower level but not zero to maintain differentiation tariff according to routes for the exchange and through traffic. However it is possible to maintain non-null t_1, t_2 and PR for environmental reasons.

In practical terms this implementation results in different treatment of the users, according to whether or not they are resident in areas Z1 or Z2:

- these residents must buy a pass if they drive at peak hours, which gives them the right to drive on the internal network of areas Z1 and Z2 and to take freely all the expressways R1, R2 and FL. They must post the pass to show that they are in order, controls being practised in a random way at these hours on the whole of areas Z1 and Z2. Apart from these hours, they do not need any pass to drive;
- the non-residents must pay in any event the pass t_0 at the time when they enter in the expressway network of the agglomeration, whether they penetrate there indeed or they get round it by the external bypass R1. Those who only get round the agglomeration must present this pass at the exit of the expressway network of the agglomeration or pay the toll t_0: this control has an interest to discourage the free-rider behaviour which would consist in for the through traffic entering directly on R1 to benefit freely from this bypass. The non-residents who want to enter into the agglomeration must more or less cumulate the passes (t_1 or t_{12} or t_2) according to the place where they go and pay more or less according to the period of the day.

Table 2 in appendix gives some examples of the situations met by the user according to the origin and the destination, the route and the period of travel.

CONCLUSION

We firstly described in which space configurations conflicts for road use occurred, between various categories of users. We then exposed which were the various goals of maintenance of accessibility which could be pursued by the authorities at various levels, European, national, regional and local ones.

The strategy to follow regarding simultaneous management of supply and demand, is based mainly but not exclusively on the use of road tolls. The drawbacks of exclusion mechanism by the way of road pricing show that priorities must be fixed, which will be assigned to the various categories of users: these priorities are defined so as to implement an optimal strategy according to objectives of accessibility and under the constraints of financing, environment and equity. Moreover these drawbacks show that a redistribution action must be undertaken by the authorities. The conclusion of this analysis is that the intervention of the public authorities is necessary, even in a more deregulated context than today.

The description of the technical toll systems and their respective advantages shows that a combination of the elements of open and closed systems offers the potentialities of adequate response to the objectives of differentiation of users categories: this differentiation is possible according to entry and exit points in the system, the routes in the network and the periods of road use.

Finally we demonstrated on an example the feasibility of such a strategy of demand management under the constraints exposed above: a system of pseudo-closed toll is conceived to be implemented on a specific case combining the access by corridors in an urban network of multiple bypass rings.

However the application to a concrete case study, and especially fixing the relative levels of tolls, needs more study, with revealed and stated preference surveys and models, about the price-time arbitrage by individuals when choosing their travel mode and route.

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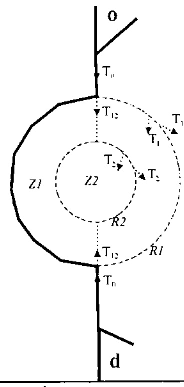
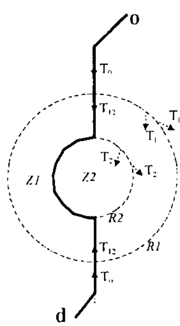
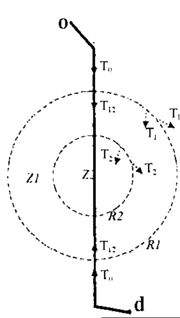
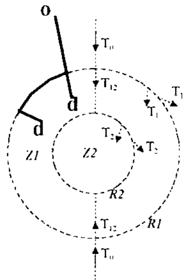
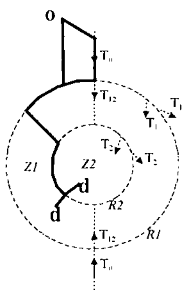
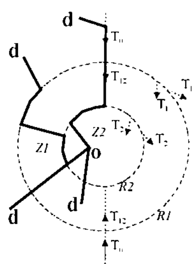
APPENDIX

Table 2: Examples of levels of toll to be paid according to origin (o) and destination (d), route and travel period

Origin-destination	Route	Peak level	Off-peak level*
from Z_0 to Z_0		t_0	t'_0
from Z_0 to Z_0		$t_0 + t_{12}$	$t'_0 + t'_{12}$
from Z_0 to Z_0		$t_0 + t_{12} + t_2$	$t'_0 + t'_{12}$ (+ t'_2)

Origin-destination	Route	Peak level	Off-peak level*
from Z_0 to Z_1		t_1	(t'_1)
from Z_0 to Z_1 from Z_0 to Z_2		$t_0 + t_1 + t_2$ or $t_1 + t_2$	$t'_0 + (t'_1) (+ t'_2)$ or $(t'_1) (+ t'_2)$
from Z_2 to Z_0 from Z_2 to Z_1 from Z_2 to Z_2		non-residents : $t_1 + t_2$ unless daily pass already paid by the non-resident on incoming trip residents : PR	non-residents : $(t'_1) (+ t'_2)$ unless daily pass already paid by the non-resident on incoming trip residents : (PR')

* (+t') means an eventually null tariff