International Transport Forum

Urban Toll: Rethinking Acceptability Through Accessibility

Discussion Paper

170

Roundtable

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The International Transport Forum

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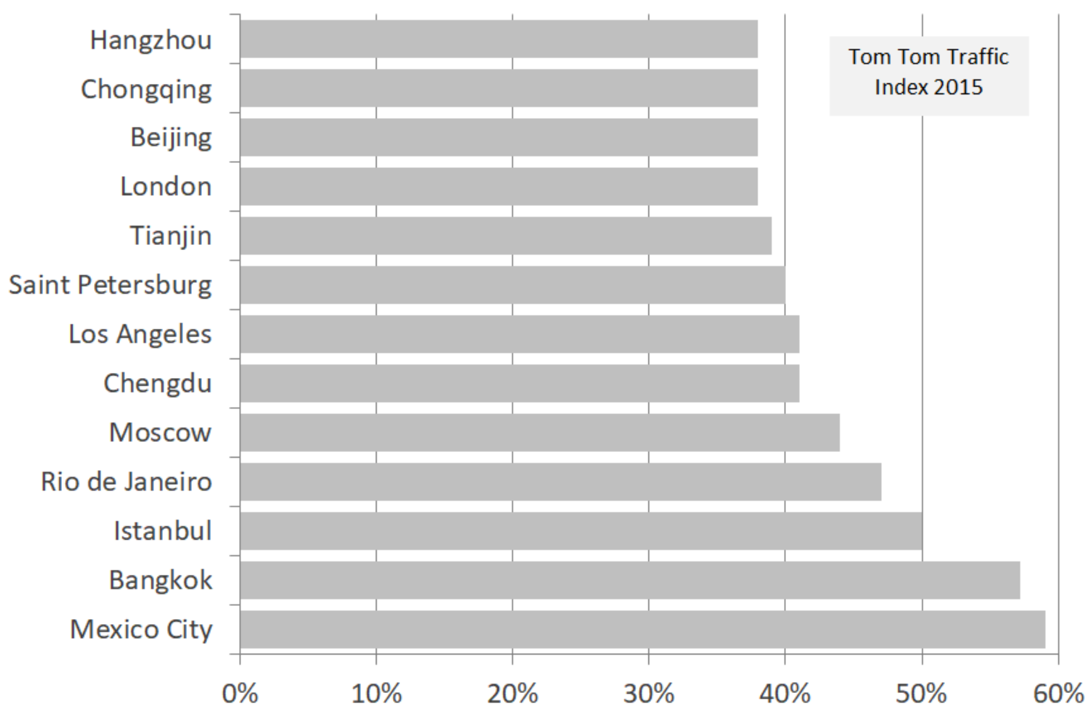
Introduction

Road congestion is a fact of life in most major cities of the world. One of the most obvious consequences is loss of time due to the decrease in travel speeds. Figure 1 illustrates that in a range of cities with more than 5 million inhabitants, travel times during peak periods are 40% to 60% higher than in off-peak periods.

Figure 1. **Additional travel time due to congestion (cities of more than 5 million inhabitants)**



Time losses are not the only side effects of road congestion. Traffic noise and emissions of gaseous pollutants, greenhouse gases and particles are all exacerbated by congestion. To reduce these external costs, many public authorities are targeting vehicles by limiting or prohibiting the most polluting, especially diesel, vehicles. However, replacing the vehicle fleet by less polluting vehicles (whether they are autonomous) will not solve the problem of road congestion if overall car traffic is not reduced. For this reason, some cities have introduced congestion charges that, by reducing traffic, aim to reduce both congestion and pollution.

Congestion pricing was first proposed by the British economist A.C. Pigou (1883-1960) almost a century ago . Since then, it has been a very active research topic in transport economics. Thousands of scientific articles have been published to show that congestion charging is a solution to congestion problems. Yet few cities have implemented urban tolling. While parking pricing is now widespread among cities, the same is not true for congestion pricing. Motorists as well as most local politicians are not in favour of congestion pricing. The outcome of distributive effects on society makes it an ambivalent topic. Pricing of congestion is not beneficial for everyone: there are winners and losers. Implementing congestion charging requires questioning its acceptability for citizens. The first part of this paper explains why one should not solely focus on travel times but also consider the issue of space consumption. In the second part, we show how the concept of accessibility, which takes into account both the time and space consumption, can help in addressing the issue of acceptability.

Road pricing: The acceptability issue

This section explains why congestion charging is presented as a solution by economists but considered as a problem by motorists and public decision makers. To understand this difference of opinions we present what is at stake with a strong focus on the acceptability issue.

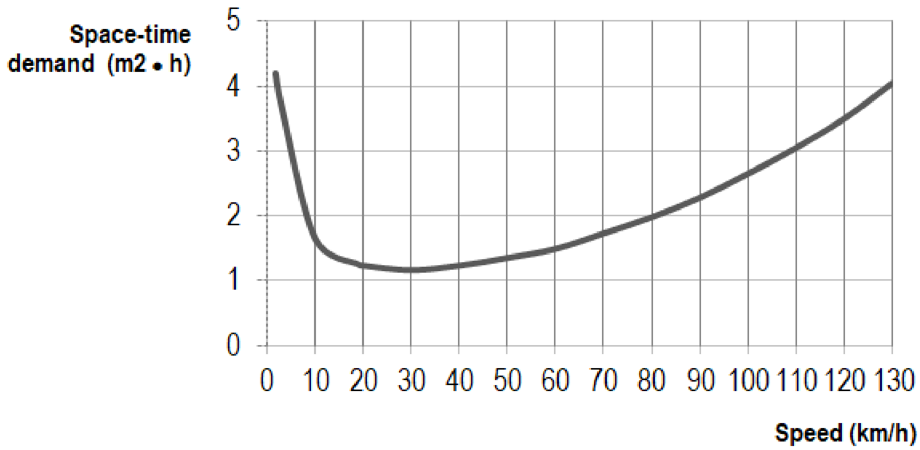
Congestion pricing: Thwarted evidence

The principle of providing free access to road infrastructure is not unfounded from an economic point of view. Roads are a collective good characterised by an indivisibility of use (with neither excludability nor rivalry) to which are added positive external effects for the community in the form of lowering the cost of mobility. For this reason roadways are generally free to access. Justifying the implementation of a toll requires consideration of the negative external effects of road traffic, for example congestion. The latter arises from a scarcity of road space and results in wasted time.

Road congestion: From space consumption to time losses

In 1920, when AC Pigou presented its famous example of internalising congestion costs by imposing a toll, his main objective was to maximise traffic flows by optimally distributing vehicles between two competing routes. Almost simultaneously, in the United States, traffic engineers were also interested in the fluidity of traffic flows. They introduced the concept of space consumption and derived it from speed-flow curves. The insights gained are depicted in Figure 2; the faster a vehicle moves the more space it consumes. As the car moves both in space and time, trips can be interpreted as a consumption of space-time which is expressed in m^2•hour (see Annex). Between 20 km/h and 40 km/h, a car consumes a little more than 1 m^2•hour whereas at 130 km/h it consumes nearly 4 times this.

Figure 2. **Speed and space-time consumption of a car**

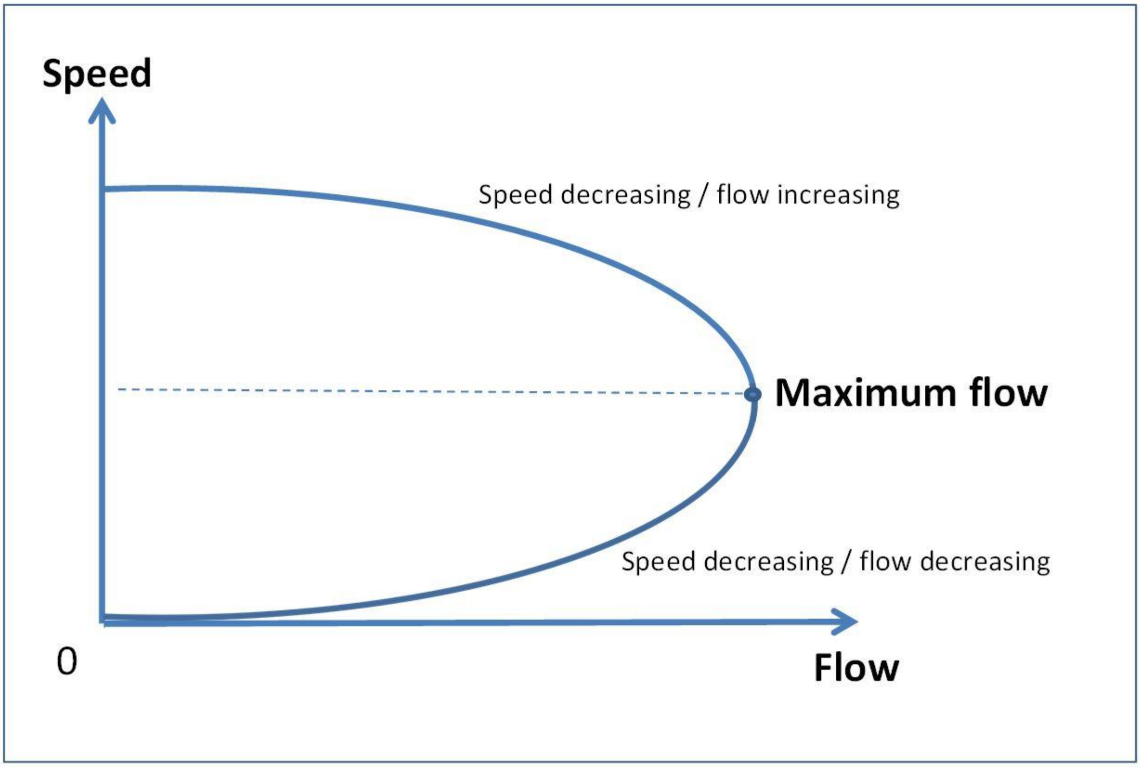


Source: Héran and Ravalet (2008)

This over-consumption of space due to speed can be explained by the necessity to increase safety distances between vehicles. At 130 km/h, it is unsafe to drive bumper to bumper. Note that at a very low speed, consumption of space-time is also high; in this case flow is too low. There is an optimal speed that is neither that of walking nor that of the car's maximum speed. In dense areas, the optimal speed from a socio-economic perspective - the one that minimises the consumption of space - is between 20 km/h and 40 km/h. This is usually misunderstood by motorists. While their vehicle can run very fast and is allowed to run at higher speeds by regulations (with authorised speeds of 90 km/h, 70 km/h or 50 km/h depending on the road type), the socio-economic optimum is rather between 20 km/h and 40km/h when road space is threatened by traffic saturation. A motorist will always feel congestion because the optimal speed from a socio-economic optimum is not in line with his desired speed.

This is summarised in the speed-flow curve presented in Figure 3. It shows that when the number of cars that circulate is small, travel speed is high but traffic flow is low (top left of the upper part of the curve). An increase in traffic flow first causes a speed reduction (downward sloping part of the upper part of the curve, also known as the laminar flow regime) then, with more cars, traffic flow slows. From a certain point (about 70 000 vehicles per day in the case of 2 x 2 lanes), speed and flow decrease together. This is the beginning of the forced regime, the lower part of the curve. At worst, everyone is stopped; it is no longer a road but a parking lot (lower point on the bottom left of the curve).

Figure 3. **The speed-flow curve**

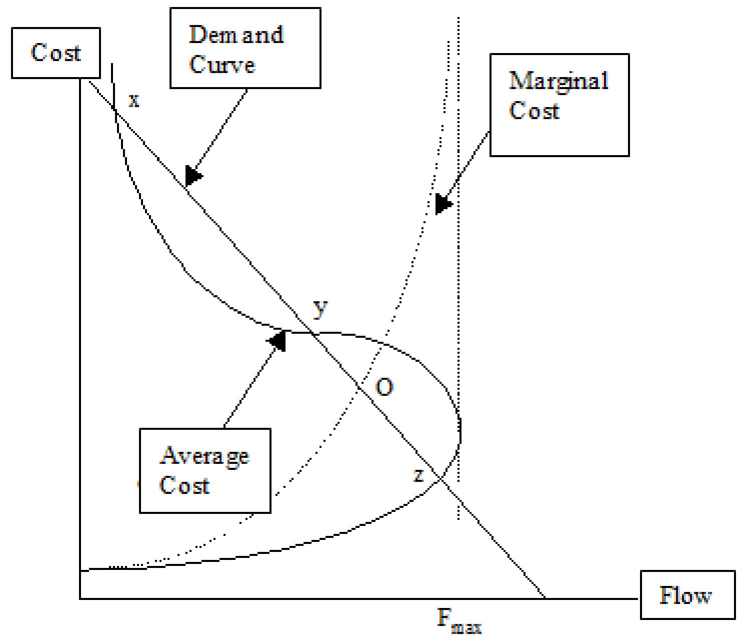


Source: Crozet and Mercier (2018)

The speed-flow curve clarifies the misperception of congestion by drivers. They are not the only ones faced with a puzzle. The same is true for public decision makers. Facing complaints of motorists about time lost in traffic jams, local public decision makers consider that congestion is the result of an under-provision of roads. It therefore makes sense for them to invest in road extensions.

Here we have a fundamental hiatus between individual and collective points of view. Motorists seek to minimise their time budget (or maximise their speed) as time is a scarce resource for many of them. From a collective point of view, the scarcest resource is space. Space is critical as it becomes even scarcer as speed decreases with the number of vehicles on the road. It is possible to derive costs from a speed-flow curve. Assuming that travel costs are limited to the cost of time, and knowing that travel time evolves as the inverse of speed, we can derive from the speed-flow curve an average cost-displacement curve for a given distance and time value. This gives the average cost-flow curve depicted in Figure 4 (with the x-axis being the flow and the y-axis being the generalised travel cost). Since the cost of time is an inverse function of speed, generalised cost increases sharply when speed is decreasing.

Figure 4. **Demand, average cost and marginal cost**



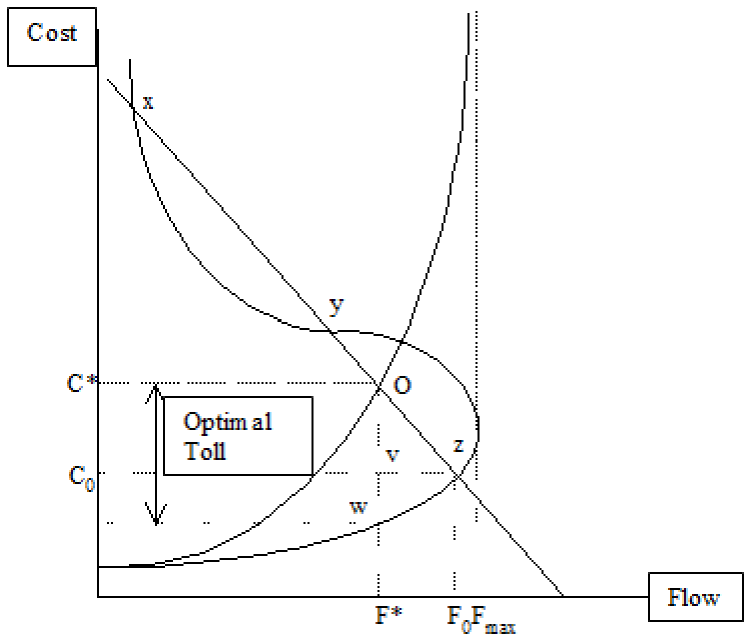
Source: Adapted by the authors from Walters (1988)

The maximum flow F_{max} is obtained at a certain level of congestion. The lower part of the curve corresponds to the laminar regime. When the number of motorists increases the speed decreases but the flow continues to increase. Once maximum capacity is reached, this is the beginning of the forced regime: an increase in the number of vehicles in circulation causes a decrease of the speed and a reduction in the flow. The difference between the average cost and the marginal cost is the external marginal cost of congestion, i.e. the congestion cost imposed by a user on other motorists. However, each user decides to use the infrastructure based on its average cost, which results in "overconsumption" insofar as the cost borne by a user is smaller than the total cost that he generates. Under these conditions, the optimal toll is the external marginal cost of congestion i.e. the difference between average cost and marginal cost.

Congestion pricing: winners and losers

What is optimal for the community is not necessarily optimal for motorists. Figure 5 shows a situation where all road users would loose from the implementation of a congestion charge. At equilibrium, in the absence of a toll, the traffic is at level F_0 and the users bear an average cost C_0. Setting a congestion charge amounts to taking a sum *Ow* which will lead to new traffic equilibrium $F^* < F_0$. A certain number of users will stop using the infrastructure and suffer a loss that depends on the travel cost of the best alternative (other road, public transport, etc.).

Figure 5. **Optimal toll and distributive effects**

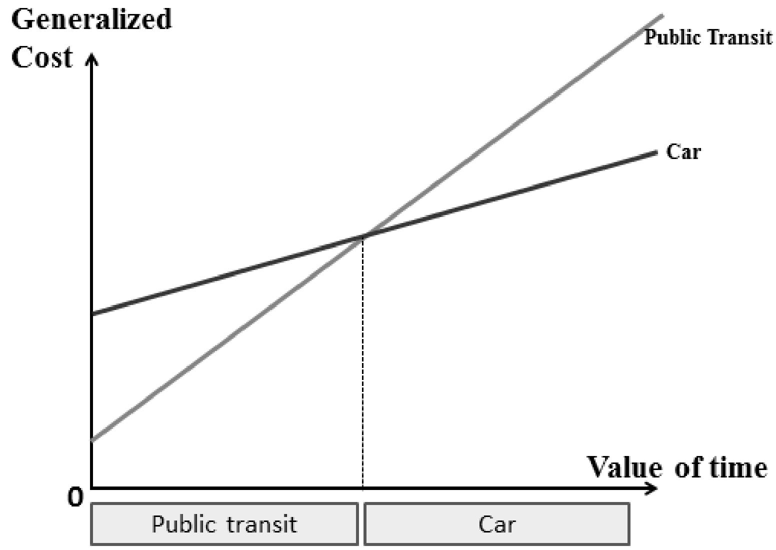


Source: Adapted by the authors from Walters (1988)

The remaining users would also lose: they pay a toll *Ow* that is (in this situation) not offset by time savings (*vw* < *Ow*). In the absence of redistribution, the toll is clearly unfavourable to all road users, and the public authorities are the only beneficiaries. If the objective of the congestion charge is a better allocation of the rare resource that is the road, its result is a distributive effect in favour of the entity that collects the toll.

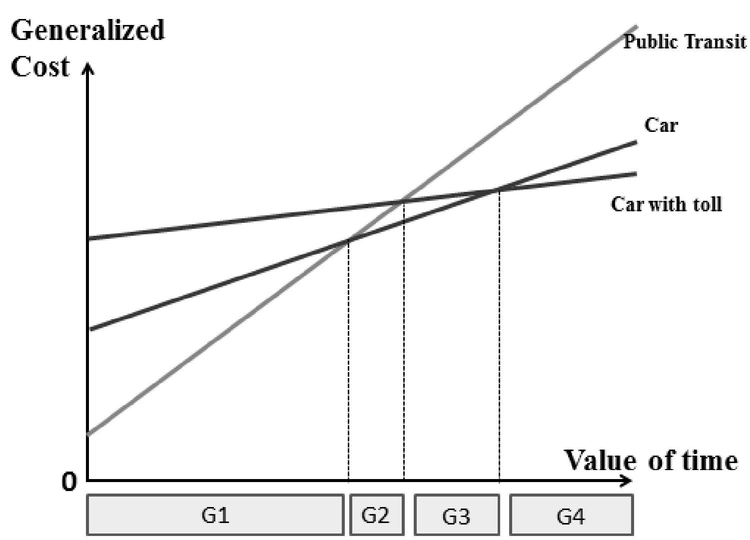
If the assumption of homogeneity of users is relaxed, i.e. if we introduce the idea that users have different time values, then optimal pricing at marginal social cost may favour users with higher value of time, the other categories losing more than their time gains. Figure 6 shows that for any given route and speed of each mode, a generalised cost (the sum of both the monetary and non-monetary costs per journey) evolves with the value of time. The monetary cost of traveling by car is assumed to be higher than the cost of traveling by public transport. In this case travelling by public transport is the optimal choice for users with low values of time. From a certain level of value of time, users will rather choose a car. As the car is faster, the generalised cost line has a lower slope. This graphical approach helps to understand the drivers of modal split and why people with a low value for time use public transport.

Figure 6. **Value of time and modal split**



What would happen if an urban toll is introduced? As shown in Figure 7, the generalised cost line of a car trip would shift. Due to the cost of the toll, the line is higher on the y-axis. But as the toll reduces congestion, the speed is higher which results in a lower slope. It is then possible to compare the situation of commuters before and after the introduction of the toll.

Figure 7. **Winners and losers of congestion charging**



Of the four groups featured in Figure 7 (G1, G2, G3 and G4), only the users belonging to G4 benefit from congestion charging. These users have a higher value of time and their generalised cost will decrease due to the speed gains. The cost of the toll is more than offset by time savings. This is not the case for G3, which continues to use cars but has its generalised cost increase. The observation is the same for G2, which shifts to public transport to avoid paying the toll. As for G1, its situation has apparently not changed, but it can suffer from deterioration in public transport quality due to crowding. When setting a congestion charge, the losers outnumber the winners. It is therefore essential to address the issue of acceptability.

How to solve the acceptability issues?

Acceptability issues are related to two distributive issues. As seen previously, congestion pricing redistributes welfare from road users to the rest of the community. Given an average value of time, the revenues of the toll are higher than the time gains of road users. The second dimension appears when we take into account the heterogeneity of values of time. In that case, congestion pricing creates horizontal inequity between users. Is it possible to solve these issues?

Congestion pricing and the double dividend

When the community is the main beneficiary of a congestion charge, one might wonder if this type of tax is preferable to others. As Jacques Drèze (1995) suggested, could congestion taxes partly replace labour taxes? The question arises since many studies have shown that the excessive cost of labour is one explanation for the mass unemployment in many European countries. This is the rationale of the "double dividend", which aims to encourage governments to substitute environmental taxes for other forms of tax, considered to be more distortive for the economy. The expected result is a double benefit:

- The reduction of external effects such as congestion and pollution.
- A better functioning of labour market and a lower unemployment rate.

Why then has such a powerful instrument not been implemented? Should we consider that public policies lag behind economic thinking? Or should we take into account the fact that the double dividend is not as obvious as it sounds?

The first weakness of the double dividend hypothesis applied to the congestion charge is that congestion costs are very often overestimated. Calculations such as those presented in Figure 1 tend to assume a situation of fluidity that exists only when the infrastructure is empty.

The second weakness arises from the presence of winners and losers in the event of an urban toll. If there are welfare losses due to congestion, there are also some losses under congestion pricing. We are then led to ask whether, from the point of view of public policy, there is not a certain preference for congestion. If asked to choose between those who have a high value of time and the others, public decision makers would choose the latter, the most numerous group, because they do not want to transform the roadways into a club good reserved for a minority of the population. If they decided to do that, then they should organise a compensation system. Therefore, the key question becomes: what do we do with the money from the toll?

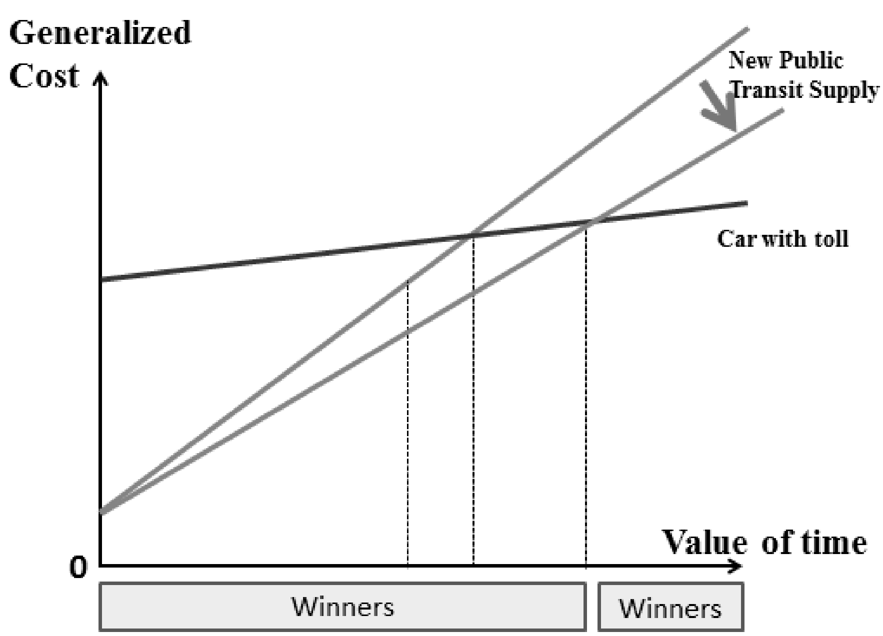
In the survey of Verhoef et al. (1997) road users expressed the following preference for the use of toll revenue: first of all, investment in new roads, second, reduction in vehicle ownership taxes, third, reduction in fuel taxes (the last two revenue uses could considerably weaken the effects of congestion pricing), fourth, investment in public transport, and finally subsidies to public transport. It suggests that the use of toll revenue to finance road infrastructure as a substitute for general taxes is politically attractive. Nevertheless, we could wonder if users can correctly assess the amount of tax needed to finance the construction of new infrastructures in high population density areas. Moreover, people probably do not take into account that some of the new transport infrastructure would probably be tolled so that financing new infrastructures with the revenue of the toll would probably not reduce the inequity induced by the congestion toll.

Small (1992) proposed schemes that allocate revenues. In Small's scheme, revenues are used to reimburse travellers as a group (but direct redistribution of toll revenues could weaken the efficiency of congestion pricing), to offset regressive taxes and to fund new transportation services, and especially public transport. But is the improvement of public transport the best option?

Congestion pricing and public transit

One way to make the toll acceptable is to offer users compensation in the form of improved public transport. Thus, in London and Stockholm, a part of the toll revenue is earmarked to finance public transport. It is a condition of toll acceptability as shown in Figure 8 which presents an extreme situation where everyone is a winner. Compared to Figure 7, we have imagined a significant improvement in the public transport supply by increasing frequency and/or speed. In this case, only drivers with a high value of time keep using the road. All the others rely on public transport because their generalised cost has become lower than in the previous situation.

Figure 8. **Public transit improvement: a win-win game**



Such a win-win situation is possible in certain corridors, when an efficient public transport system is in place. But it cannot be extended to all origins-destinations. Most often, a door-to-door trip by public transport is slower than by private car. But it is nevertheless necessary to encourage the use of public transport because even if they can represent a waste of time for the users, they allow a better use of the space as shown in Table 1. By taking again the notion of consumption in $m^2 \bullet h$, we see that an automobile consumes ten times more space than a bus at rush hour.

Table 1. **Compared space-time consumption**

	m^2.h/veh km	Occupation rate	m^2.h/traveler km	Difference / pedestrian
Pedestrian	0,3	1	0,3	1
Cyclist	0,6	1	0,6	2
Two-wheeled motor vehicles	1,7	1,05	1,6	5
Cars	1,8	1,3	1,4	5
Bus (12 m)	7	17	0,3	1,4
in peak hour	7	50	0,15	0,5
Articulated bus (18 m)	10	23	0,3	1,4
in peak hour	10	70	0,15	0,5

Source: Héran and Ravalet (2008)

Space consumption therefore remains the main challenge for urban transport policies. The issue of congestion charging, too often focused solely on gains or losses of time, must be examined by taking into account the optimal consumption of space from a collective point of view. Maps and indicators of accessibility can contribute to this.

Accessibility: A concept to address "the tension between acceptability and economic efficiency"

Westin *et al.* (2016) outline the paradox between the search for maximum economic efficiency and the acceptability of transport policies. They build on the work of Steg (2003) to conclude that "efficient instruments in the transport sector are not acceptable while acceptable policies in general are less efficient". Raux and Souche (2014) show economic efficiency is just one component of acceptability. Other dimensions of equity are: horizontal, vertical and spatial. Horizontal equity is based on the user pays principle with an equal opportunities criterion. Vertical equity is based on the welfare of the most underprivileged with an attention for social inequalities and redistribution issues (Raux and Souche, 2001).

Therefore, the major issue is to understand how to reconcile efficiency and equity dimensions introducing a spatial dimension. That is to say, to what extent and under what conditions a spatial accessibility based approach might help to resolve the acceptability issue? Through the lens of the accessibility indicator, the answer might lie with the coupling of spatial level and economic dimension weighted by the individual perception of transport costs resulting from a new charging.

Accessibility is a central concept in the context of evaluating transport projects for urban environments. Accessibility is defined as the ease with which activities can be reached given a starting point and a transport system (Morris et al, 1978). By aggregating many dimensions (time, individual and transport dimensions), the concept of accessibility thereby goes beyond the framework of the transport system and its purely temporal dimension, associating it with a spatial dimension (Geurs and Wee, 2004). The notions of travel and time are combined with a notion of density and space. Accessibility should, then, reflect the spatial organisation and the quality of the transport system that provide individuals (alone or in groups) with the opportunity to participate in activities located in different areas (Geurs and Wee, 2004).

Measures of spatial accessibility integrate indicators of trip purpose (ie, the range of opportunities) with the resistive element (i.e. the generalised travel cost). These accessibility measures summarise the relationship between the transport system and the locations of activities and opportunities.

If spatial accessibility refers to urban activities and transport systems, it also includes a social and human dimension with individual and collective inequities to access day-to-day services (CERTU, 2004).. Locations of employment and essential services and their proximity to transport networks can have an impact on social inequalities and disparities of accessibility. This is reflected in the differing perception and sensitivity towards transport costs.

By comparing the amount of opportunities (in terms of both quantity and quality) to be reached by individuals at given trip costs, accessibility measures can help transport practitioners to understand how individuals make location and travel choices. This in turn will provide valuable insights to inform transport policy decisions and regional planning. For example, measures of accessibility of individuals can be combined into an accessibility index to inform land use planning to maximise the benefits to the community at large. While most literature makes only fleeting references to the relationship between public acceptability and accessibility, works do exist that describe the link between the two (e.g. Schade, 2017; Westin et al., 2016 and Steg, 2003).

Accessibility measurement and theoretical background

To understand the link between accessibility and public acceptability, this section utilises the results of a research using a gravity-based accessibility measure to simulate the Lyon metropolitan area in France.

Gravity-based accessibility measure takes the following exponential form:

$$A_i = \sum_j D_j e^{-\beta C_{ij}}$$

Where:

- A_i is accessibility from zone i
- D_j is the opportunities available in zone j
- β is a parameter reflecting the sensitivity to the generalised cost of travel
- C_{ij} is the generalised cost of travel between zones i and j.

This gravity-based accessibility measure assumes traffic gravitates towards activities in each area based on the physical connectivity between zones. It is expected to increase with the amount of potential opportunities but relative importance declines the further away opportunities are from the origin (El-Geneidy and Levinson, 2007). This measure focuses on opportunities available and not just on opportunities actually consumed by people. Individual activity schemes are not considered.

The following example focuses on the potential accessibility of the working population to jobs located on the Lyon Metropolitan Area. Indeed, job location is one of the major determinants of individuals' location choices (Thériault *et al.*, 2008). Generalised transport costs are given, for a daily peak period, as follows:

$$C_{ij} = Cm_{ij} + T_{ij} * VoT$$

Where:

- C_{ij} is the generalized cost between zones i and j
- Cm_{ij} is the monetary cost depending on distance between zones *i* and *j* and on average cost per kilometer (including fuel, maintenance and insurance costs)
- T_{ij} is the travel time between zones *i* and *j*
- VoT is the value of time.

Note that monetary costs and travel time takes into account congestion charges and traffic congestion respectively. All the parameter values are either obtained from the French government's appraisal guidance or from transport model.

Accessibility: A concept to integrate individual and local disparities

A number of researchers have studied the link between public acceptability of road pricing and income. Rienstra *et al.*, (1999) found the public acceptability of road pricing increases with income. Subsequent works tend to question this relationship (Jaensirisak, 2002; Schade, 2005 in Shade, 2017). Analyses of travel behaviour reveals that people don't react to road pricing in the same way they do to other transport policies. Perception of changes in generalised travel cost depends on transport modes or trip purposes (Bonnafous *et al.*, 2009) and individual features. However, few studies have used accessibility as a tool to analyse individualised social inequalities and socio-economic disparities in access to urban opportunities. Literature often considers an "average" individual and thus neglects the heterogeneity in preferences. Only his location differentiates a user from others.

Considering the heterogeneity in travel cost sensitivity is crucial when measuring accessibility. The resulting measure, sometimes called *social accessibility* can be analysed in relation to the distribution of socio-professional categories within the population. This highlights areas where there is a gap between perceived and offered accessibility levels.

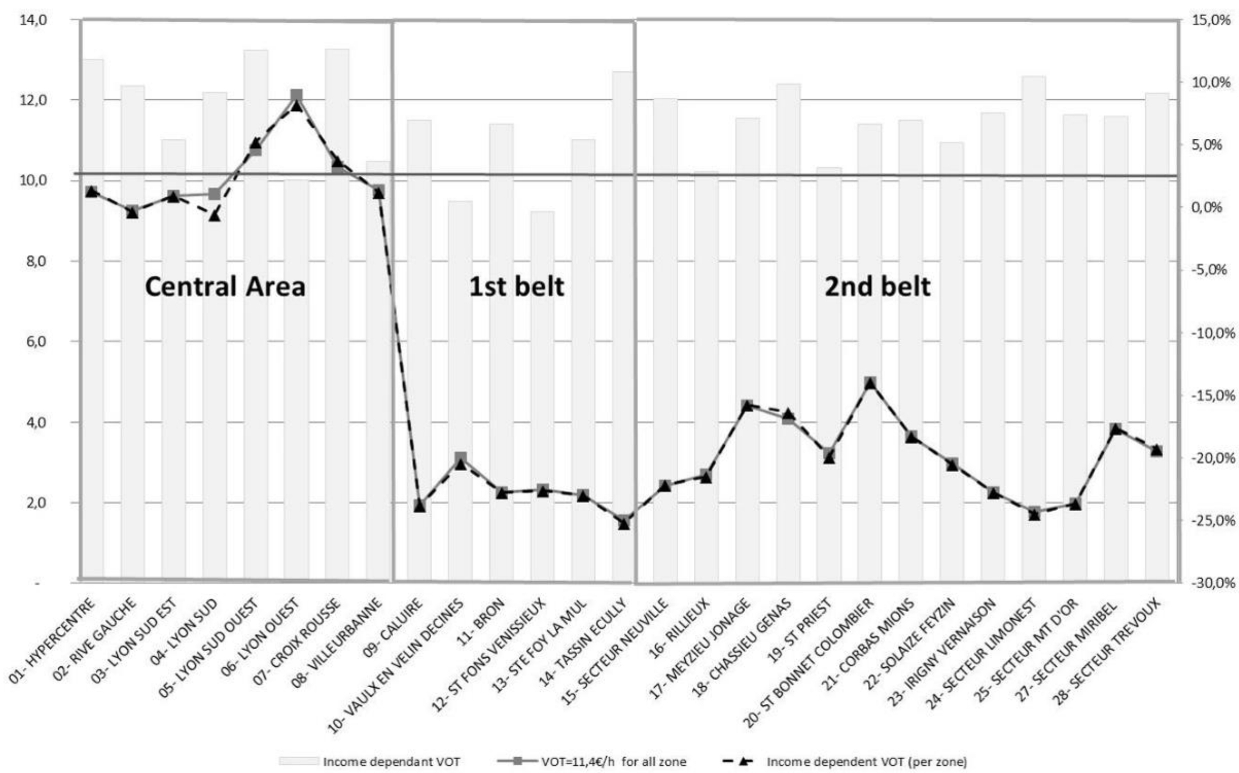
Travel cost sensitivity and income level

Value of travel time savings (or value of time in short) can sometimes be established by finding out how much road users would be willing to pay to save time. This willingness-to-pay-based value of time depends on income (average hourly wage) but also on locations and travel conditions (Commissariat général à la stratégie et à la prospective, 2013).

Taking into account individual differences in the value of time matters when assessing the impact of congestion charging on accessibility, as shown in Souche *et al.* (2016). Using an income elasticity of 0.6 to establish value of time by income level, Souche et al looked at how urban tolling can affect social inequalities in urban areas of Lyon. Simulation results show that introducing cordon charging around the city centre (municipalities of Lyon and Villeurbanne) will increase inequalities. This affects zones inside the cordon area less than areas just outside the cordon boundary. This is because individuals located in the central area tend to have higher value of time than those located outside the centre (first and second belt areas as shown in Figure 9).

Figure 9 illustrates how accessibility varies after the implementation of a cordon charge. The continuous line assumes a single, homogeneous value of time while the dashed line takes into account the variation of value of time due to income. Accessibility remains stable for the working population residing inside the cordon. Spatial distribution of income does not significantly impact accessibility. First, the value of time only varies between EUR 9.20 and EUR 13.30. Then, spatial division tends to erase pre-existing inequalities inside each zone. Accessibility variation tends to favour the 'richest' zones, the ones with the highest values of time, where accessibility decreases are relatively lower or accessibility increases higher than with a standard value of time. The wealthiest people might be more accepting of new road charges to save time. An increase in monetary travel cost is thus offset by time savings.

Figure 9. **Accessibility variation per zone following a EUR 7 urban toll implementation**



Source: based on Souche *et al.* (2016)

Travel cost sensitivity and socio-economics factors

The studies mentioned above only focus on income. Simultaneously, research has been conducted to measure the influence of other socio-economic factors on travel cost sensitivity. They reveal that the propensity of individuals to bear an increase in price is very heterogeneous. In a way, travel cost sensitivity measures the "resistance" to travel. Research conducted in the Lyon metropolitan area looked at the influence of sensitivity to travel costs on measuring accessibility. Andersson and Karlsson (2005), Johansson *et al.* (2002), Bonnafous *et al.* (2009) highlighted travel time sensitivity depends on trip purposes (Figure 10) but also socio-economic characteristics and space-time dimensions.

They also stressed the importance of gender and socio-professional categories in explaining users' sensitivity to travel time, especially in the context of work trips. In a given socio-professional category, men are more travel time sensitive than women, especially for home-based work trips. Meanwhile, travel time sensitivity decreases with social position: upper or middle managers have longer daily trips than others. The study also highlights travel time sensitivity depends on trip characteristics (constrained or non-constrained trips) and schedules. People are less time-sensitive when going to work than to other purposes, especially in peak-hour and try to limit travel time for non-constrained trips (HBO or NHBO trips, see Figure 10). Such elements are relevant to assessing acceptability in speed-reducing policies.

Figure 10. **Travel time sensitivity**

Time sensitivity for different trip purposes

Purposes*	β (full day)	β (morning peak hour)
HBW	0.21	0.18
HBO	0.35	0.37
NHBO	0.34	0.43
NHBH	0.25	0.46
NHBW	0.26	0.09

* HBW - Home-based work; HBO - Home-based other;
NHBO - Non-home based other; NHBH - Non-home based home;
NHBW - Non-home based work

Time sensitivity for different genders

Gender	β (all trip purposes)	β (HBW trips)
Women	0.244	0.13
Men	0.297	0.18

Time sensitivity for different labour categories

Labour categories	β (all trip purposes)	β (HBW trips)
Farmers	0.35	0.26
Skilled workman	0.3	0.22
Workers	0.3	0.19
Employees	0.34	0.23
Mid-management position	0.3	0.19
Managers	0.29	0.16

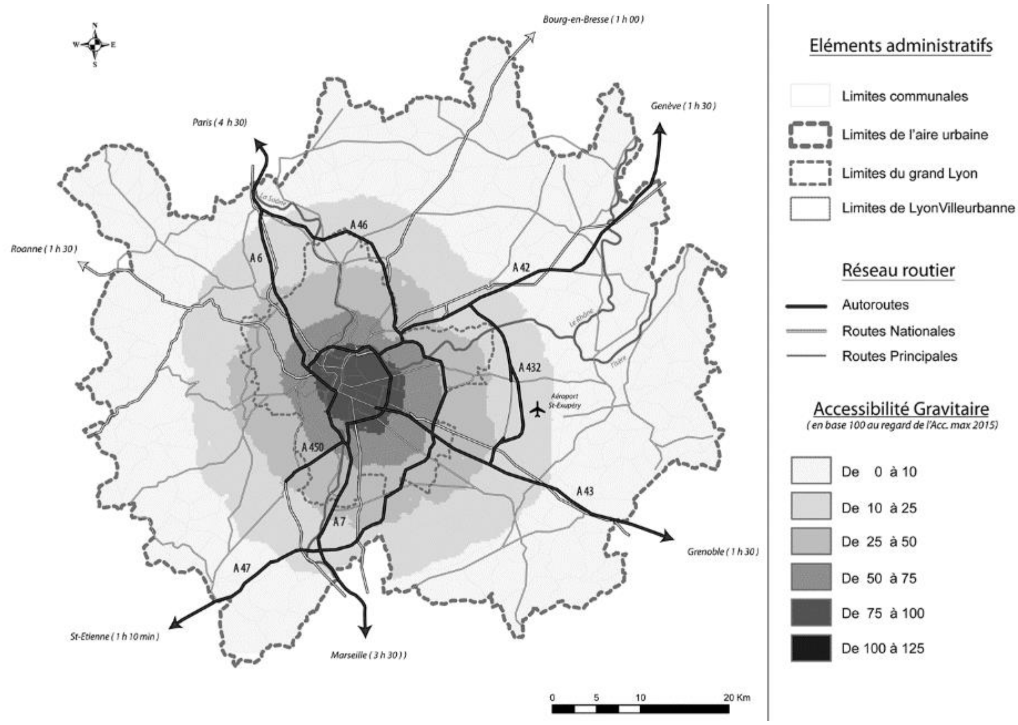
Source: Bonnafous *et al.*, 2010

Considering the differences in travel time sensitivity is essential when estimating accessibility. Crozet *et al.* (2012b) measure accessibility to employment opportunities by focusing on travel time sensitivity according to labour categories. Spatial division and data are given by local trip surveys (Enquête Ménages Déplacements, 2006).

In Figure 11, accessibility is estimated with a single sensitivity parameter, i.e. ignoring the heterogeneity in travel time sensitivity. This figure shows a decrease in accessibility the further the distance from to the city centre. Taking into account the heterogeneity of travel time sensitivity in this metropolitan scale results in a decrease of 2% of accessibility to jobs. Nevertheless, in Figure 11 all zones are not affected by the same level of decrease in accessibility. Results depend on the mix of professions of the employed population: the higher the share of management positions, the lower the travel time sensitivity and hence the decrease in accessibility. Areas in light grey are those which are devoted to industrial or agricultural activities. At first sight, it can be surprising to observe that no zone benefits from differentiating travel time sensitivity. It means that no zone is populated by a high share of managers – with the lowest level of travel time sensitivity - sufficient enough to compensate the higher sensitivity of other socio-professional categories. If managers generate a high level of trips (and therefore lower the average Beta value), they only represent 14% of employed people.

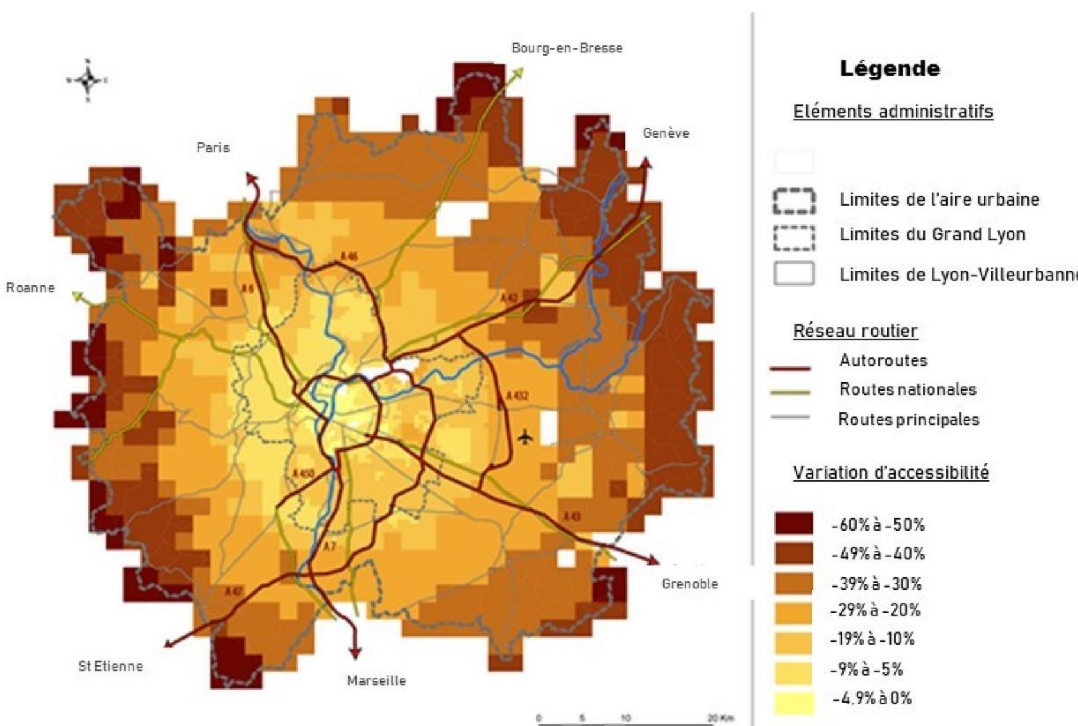
Figure 12 illustrates how accessibility varies when taking into account the heterogeneity of travel time sensitivity. It refers to a variation of accessibility from each zone of the study area to jobs located on the Greater Lyon perimeter. Figure 12 highlights areas where the people least sensitive to time are located. These people are more likely than others to accept a road charging policy. An accessibility measure with a travel time sensitivity parameter gives public decision makers a spatial vision of equity. This makes it easier to anticipate peoples' opinions and reactions towards a new road charging policy according to their location.

Figure 11. **Accessibility to jobs in Lyon (homogeneous cost sensitivity)**



Source: Crozet et al. (2012)

Figure 12. **Accessibility variation in Lyon when taking in account heterogeneous cost sensitivity**

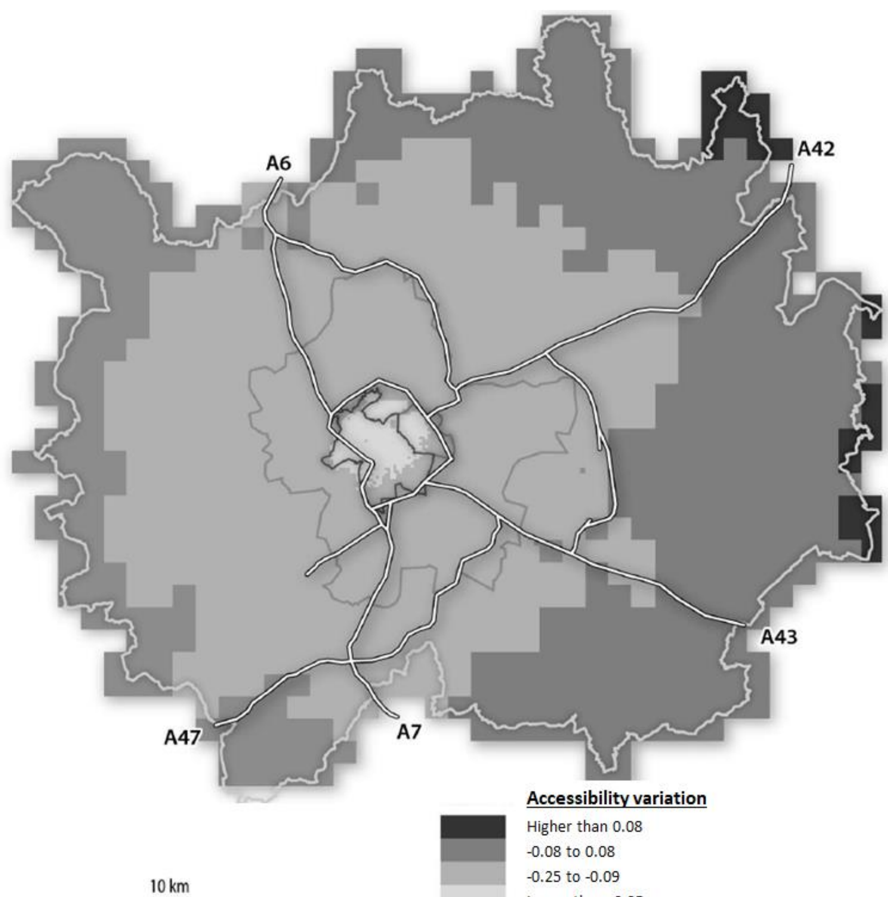


Source: Crozet et al. (2012)

Accessibility to identify winners and losers

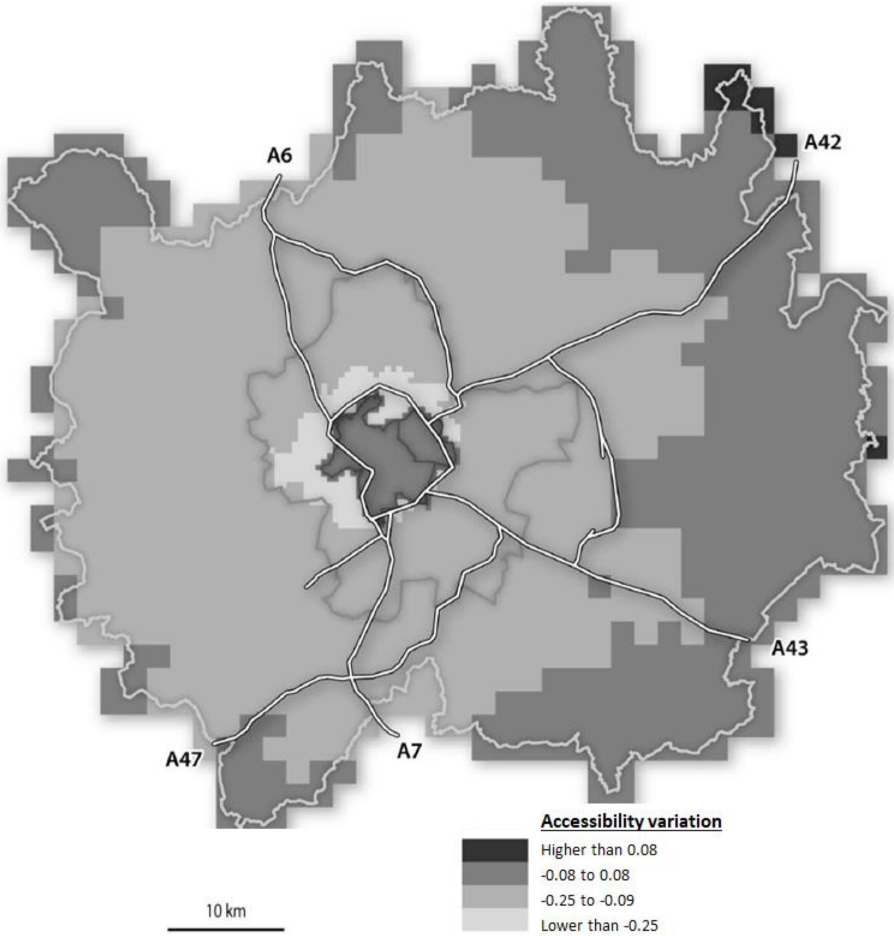
Identifying the winners and the losers of a road charging scheme is a key challenge but necessary for understanding its public acceptability. As presented by Raux *et al.* (2007) such identification must be conducted through a detailed spatial analysis. Consistent with economic appraisal, surplus variation can be computed for different population groups according to their spatial location. To illustrate this point, Crozet *et al.* (2012a) modelled two urban toll schemes in the Lyon metropolitan area. First, a zone toll (Figure 13) of EUR 3 is applied to vehicles entering or leaving the central area, regardless of the trip origin. Trips inside central areas are also impacted by this toll. Considering a value of time of EUR 11.4 per hour, such a cost is equivalent to a travel time increase of 16 minutes. Second, a cordon toll (Figure 14) around the city centre is simulated. The price remains the same but only trips entering the city centre are charged.

Figure 13. Job-access variation in Lyon for car drivers (EUR 3 zone toll)



Source: Crozet et al. (2012a)

Figure 14: Job-access variation in Lyon for car drivers (EUR 3 cordon toll)

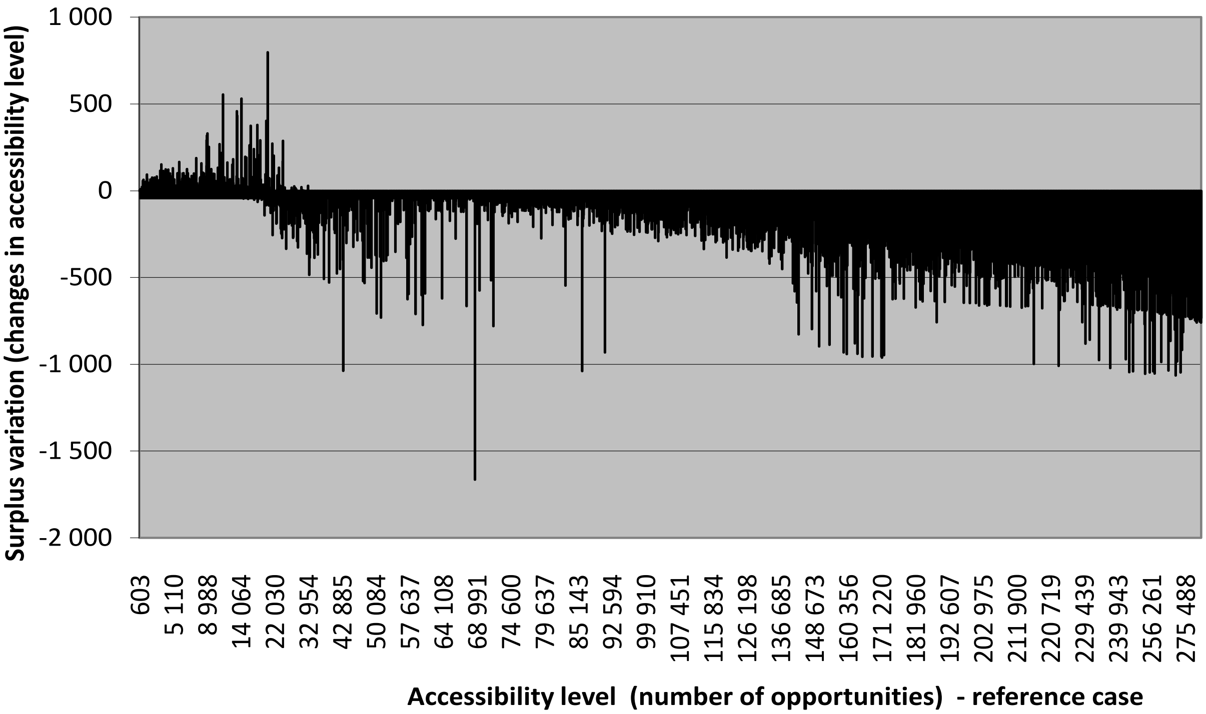


Source: Crozet et al. (2012a)

Analysis of accessibility variation by location can help to highlight those who benefit the most from a road charging scheme, and those who do not. People living in the central area benefit from the lowest travel times to access job centres based in the city centre. In Lyon, the mean travel time by car inside the city centre is 12 minutes, it works out that a EUR 3 toll is equivalent to an increase of 37% in generalised travel cost. The zone toll impacts workers living in the first belt around the city centre to a lesser extent because they have higher value of travel time to access jobs (hence a lower percentage increase in equivalent generalised travel cost). The share of the toll cost within the generalised cost is smaller for suburban residents than for residents of the inner city. The cordon toll implementation strongly impacts western areas where access to employment location decreases by 25%. Conversely, accessibility for drivers living in the central area remains constant because such people are not affected by the road charging.

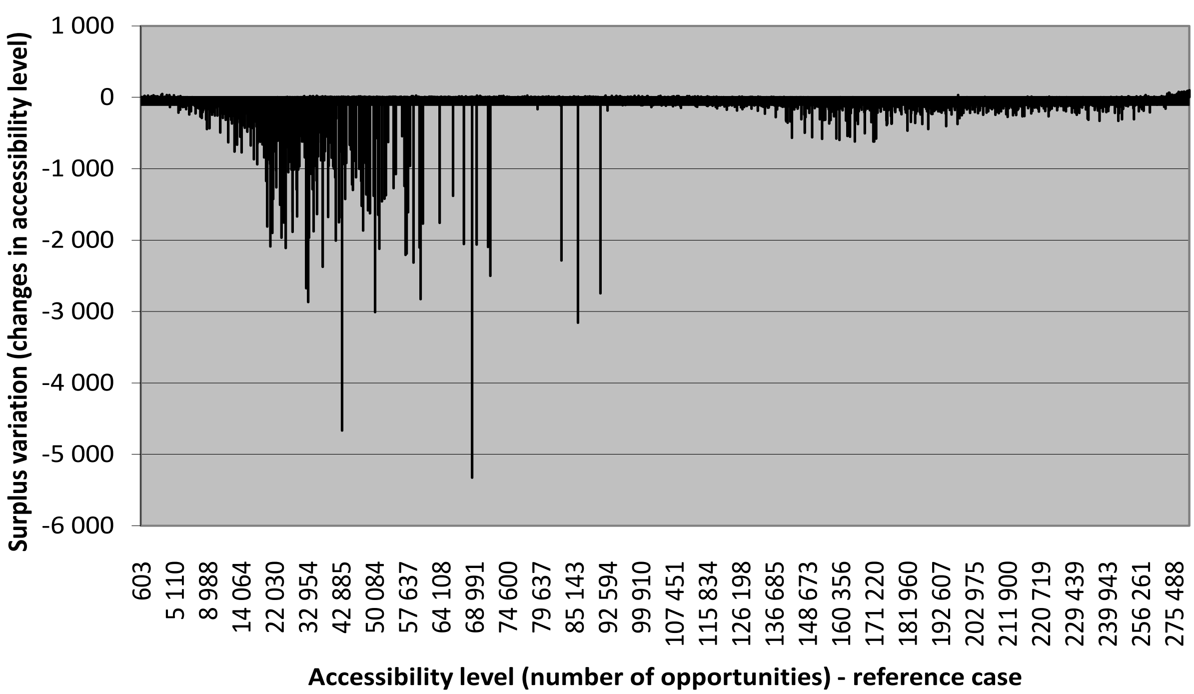
More than identifying winners and losers from the spatial equity perspective it is interesting to question the impact of such road charging from a vertical equity perspective (see Bonnafous and Masson, 2003). Figures 15 and 16 represent surplus variation following a zone and a cordon toll implementation respectively. Surplus variations are consistent with economic appraisal (Neuburger, 1971). The redistributive character of these two options is illustrated.

Figure 15. Surplus variation according to the starting accessibility level (zone toll)



Source: Mercier (2013)

Figure 16. Surplus variation according to the starting accessibility level (cordon toll)

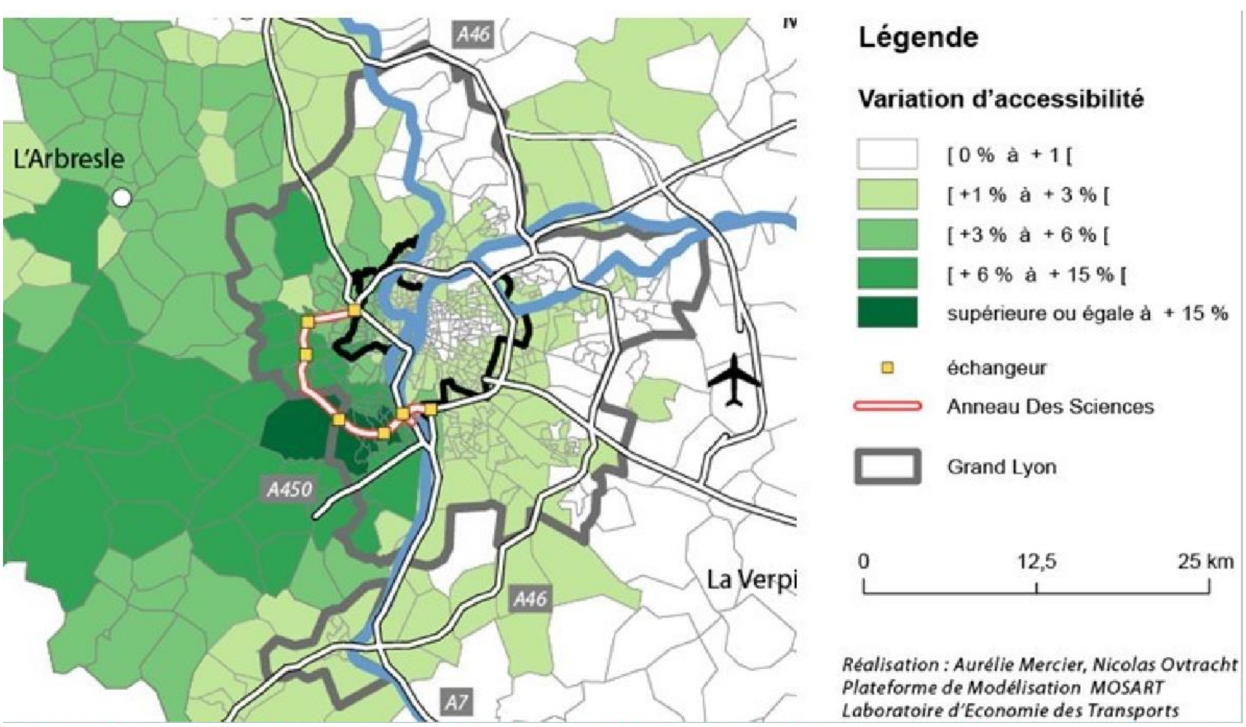


Source: Mercier (2013)

The introduction of zone congestion charging favours the less accessible areas and appears fairer than a cordon toll. Cordon congestion charging penalises less accessible areas and may create a paradoxical situation. Thus, introduction of a cordon toll diverts road traffic from suburban to central areas. With a lower congestion level and a travel time decrease, workers living in first belt or central areas are encouraged to use their car rather than public transport, especially those who live in areas poorly served by public transport. Thus, an unexpected effect of cordon charging is an increase in car use in areas where public transport is not efficient. Lower congestion is seen as a "windfall" by car drivers. This paradoxical situation raises the issue of the uneven ability among the inhabitants to pay toll charges.

This cordon charging toll example shows how crucial it is to interpret accessibility in terms of acceptability. Another example (Crozet *et al.*, 2013) is given by simulating the accessibility effects of a planned motorway ring-road in East-Lyon (called “Anneau des Sciences”). The “Anneau des Sciences” will improve the connection with western areas of the Metropolitan area. All green areas benefit from accessibility gains and there is a high probability for an increase in the number of jobs or housing. Is there any risk or opportunity loss for areas that are less accessible? The answer depends on the priorites of decision maker. Figure 17 shows that introducing a new bypass generates accessibility gains which can lead to unintended “rebound effects” with rising volumes of traffic in the metropolitan area and western urban sprawl.

Figure 17. **Accessibility variation following the Anneau des Sciences bypass implementation**



Source: Crozet et al. (2013)

In that situation, decision makers face a simple choice: either take no specific precautions to prevent these risks or adopt measures such as road charging, traffic restrictions, designated lines for public transports and carpooling, and limit the number of new buildings that decrease space for roads, etc. If the decision maker decides to prevent these risks, it raises an issue around how to compensate users who are likely to be negatively affected.

Accessibility to answer the compensation issue

Public acceptability is about more than just identifying the people who either gain benefits or suffer losses and their socio-economic features, it also concerns redistribution of impacts. Schuitema and Steg (2008) argued that transport pricing is more acceptable if revenues are allocated to the transport system instead of to general public funds. Without raising questions on acceptability and revenue allocation at the collective level (see Schade, 2017 for a literature overview), is it possible to improve acceptability by compensation at the individual level? As people tend to prioritise their individual needs over the collective needs of the community (Schuitema *et al.*2010), what type of compensation scheme can be implemented to compensate those who suffer losses and make road charging more acceptable? Considering accessibility can provide policy makers with possible solutions. This can be achieved by considering two principle antagonistic elements of accessibility: generalised travel cost and level of opportunities at destination. Considering a constant number of opportunities (under the assumption that the number, the type and the quality of opportunities do not depend entirely on public policies), road charging compensation can be made by a time or a cost compensation.

Time compensation

Urban road charging simulations in the Lyon metropolitan area (Souche et al., 2016) showed a EUR 5 cordon toll generates a 5% car traffic decrease in the city centre due to lower incoming traffic. This decrease impacts travel time by car: a worker located in the city centre has a time gain estimated at 30 seconds to reach inner city jobs and 40 seconds for suburban jobs. These time savings may seem minimal but when compared to the average travel time per trip (around 8 minutes for inner city trips and 20 minutes for other trips within the metropolitan area), they represent a significant gain annually.

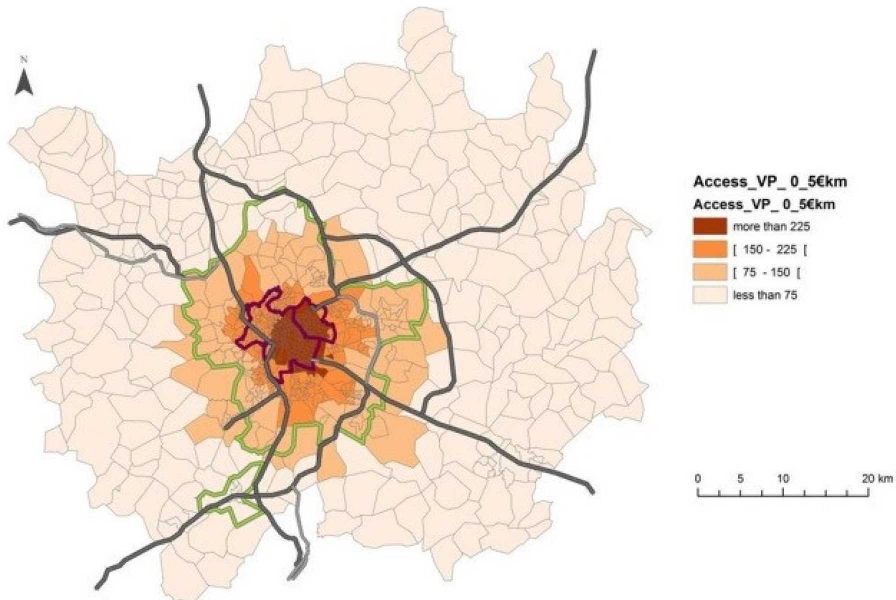
Conversely, as the toll boundary surrounds the zone with the highest number of jobs, workers living in the peripheral zones must pay EUR 5 to reach the jobs in the centre (Souceh et al., 2016). This higher monetary cost is not offset by the time saved resulting from less vehicle traffic. Souchel et al estimated that a 4% reduction in traffic is equivalent to an average time saving of about two minutes to reach the centre from the different Metropolitan Area outskirts. With a value of time (VOT) of EUR 11.4/h, it would need to achieve a time saving of 26 minutes or more to offset the cost of the toll.

Time compensation gives rise to a number of questions already mentioned. Travel time gains, due to decrease in road traffic will mainly benefit people located in central zones. In suburban areas (mainly in the first belt) where speed is higher, a decline in traffic cannot offset an increase in monetary costs. Similarly, travel cost sensitivity is lower for locations where the average income is higher (in this case, city centre or western inhabitants).

Cost compensation

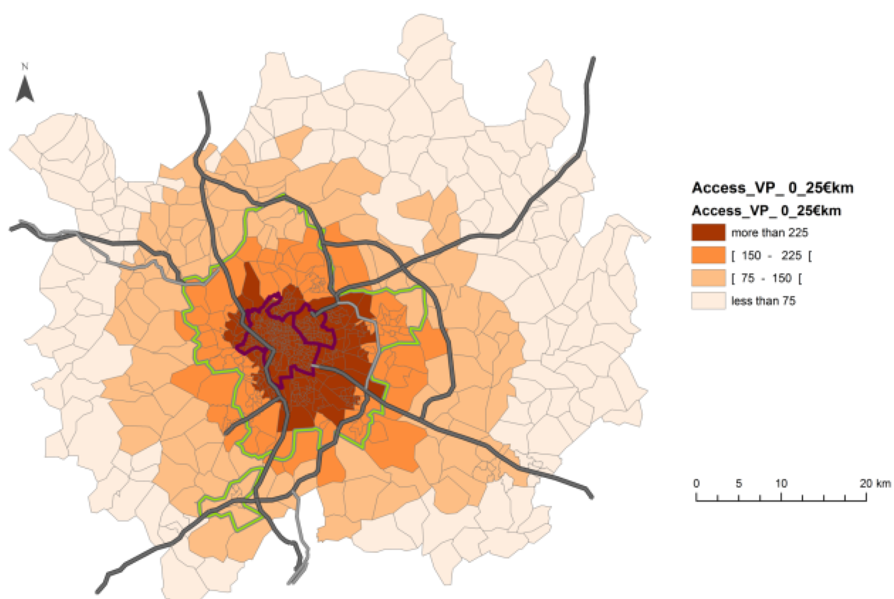
In the event of a monetary or a time cost increase for car drivers, and where a modal shift to public transports is not possible, road charging can be offset by encouraging people to share their vehicle. A number of new road infrastructure projects (or modernisation and requalification of existing roads) have one lane reserved for public transport or carpooling. This public decision sends a signal to car drivers that encourages carpooling whenever possible. However, travel time gain depends on the level of traffic in reserved lanes and is likely to decline with the increase in traffic that could come with the success of carpooling. For car drivers, the real benefits are monetary gains (fuel and congestion costs are divided between all vehicles occupants). Figures 18 and 19 highlight the increase of accessible areas in Lyon following the halving of monetary costs due to carpooling (occupancy rate: 2 people per vehicle). Accessibility gains are mainly focused on eastern areas, close to highways or motorways in Lyon.

Figure 18. **Baseline car accessibility**



Source: Crozet (2014)

Figure 19. **Car accessibility using carpooling (occupation rate: 2p/veh)**



Source: Crozet (2014)

While time compensation is observed in the city centre and in the western first belt, cost compensation benefit car drivers located in eastern areas. Eastern areas have a highly meshed network and costs reduction allows car users to go further for a given cost or to divide monetary costs for a given destination.

Conclusion

Congestion charging was proposed by A.C. Pigou almost a century ago. It has become an important research field in transport science to the point of being widely debated for transport economists. However, despite the universal nature of congestion in urban areas, few cities have adopted the recommendations of researchers. This is not the result of ignorance, but of great caution against the distributive effects of urban tolls. When they are introduced, there are potentially more people who suffer losses than the number of people who gain benefits. The key question for the public decision maker becomes not the congestion charge itself but its acceptability by society.

Many studies of acceptability issues of transport policies report barriers and difficulties in accepting urban road pricing strategies. Among them, household income, transport pricing structure and revenue allocation are the most important. Dealing with the issue of acceptability therefore comes down to wondering what forms of offsets should be put in place to ensure that the collective gain of the toll benefits the greatest number of people in society. In this paper, we have tried to answer this question using the concept of accessibility.

Introducing the concept of accessibility (with a gravity-based approach) makes a significant contribution to the debate and provides useful insights for decision makers. Indicators and maps of accessibility make it possible to search for an optimal use of urban space (the rarest collective resource), and redirects the focus away from an individual's point of view about loss or gain of time to address acceptability issues in a holistic manner. Such an approach justifies the priority given - including in terms of public funding - to the modes that consume the least space per passenger km. Public transport therefore plays a role and can benefit from part of the revenues from the congestion charge. It is a way to improve its acceptability. We have also shown that more sophisticated forms of compensation can be envisaged, taking into account the distribution of income and values of time.

A vertical equity analysis using traditional economic assessment tools can lead to a wider range of offsets. It is therefore necessary to take into account the variations between willingness-to-pay and willingness-to-accept among people and consideration of their travel cost sensitivity. High-income individuals will pursue a "time gain objective" and will more readily accept road charging if travel time decreases at the same time. But disparities - measured by income and/or socio-economic features - can also be analysed from a spatial viewpoint in terms of equity. For instance, people on moderate incomes will pursue a "price objective". In such cases, offset strategies can be applied with a decreasing monetary travel cost through the low price of public transport but also, with the digital revolution, through ride-sharing.

It is important to note that the incentives for shared mobility are not focused on time savings but on a better use of the space available in cars. It is thus obvious that the development of connected vehicles, even autonomous, is of interest to the community only if the load factor of automobiles increases. The consequence of the development of shared mobility could be an unexpected revival of congestion charging. The urban toll would then target empty vehicles. It would not be justified by the time savings of payers but by their overconsumption of urban space. One hundred years after the pioneering work of Pigou, the congestion charge is more relevant than ever, but on a renewed basis.

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Annex: The space-time consumption measurement

The demand for space-time of circulation increases very rapidly with speed because both the inter-vehicular distance and the average width of the grip per lane of traffic increase mainly with the square of the velocity. The time saved by increased speed limits this progression (Héran and Ravalet, 2008). The traffic space-time consumption is written as:

$$Cd_k = SD * T_k$$

with:

Cd_k the demand for space-time of circulation per kilometre,

SD the dynamic area,

T_k the time to travel 1 km.

We assume $T_k = {}^{1}/_{3,6V}$ with V the speed.

Thus:

$$Cd_k = SD / 3,6V$$

Dynamic Area is the area consumed by a moving vehicle (SD) and is calculated as follows:

$$SD = (L + DI) * LME_F$$

with:

L the length of the vehicle (we assume L=4 metres for a private car)

DI the distance between oncoming vehicles (we assume $DI = V + 0,01371 * V^2$)

LME_F the average width of physical footprint per traffic lanes (we assume $LME_F = 2,2 + 0,0052\, V^2$)

For details about the calculations, see Héran and Ravalet (2008) (pages 31 to 34)

Then:

$$Cd_k = ((4 + (V + 0,01371 * V^2) * (2,2 + 0,0052\, V^2)) / 3,6V$$

And:

$$Cd_k = 2,444V^{-1} + 0,611 + 0,014156\,\mathrm{V} + 0,001444\, V^2 + 0,0000198\, V^3$$

International Transport Forum

Urban Toll: Rethinking Acceptability Through Accessibility

This paper highlights the necessity of a spatial approach to addressing the acceptability problem of road tolls in cities. Few cities have implemented urban congestion charges because of limited public acceptance and perceived distributive impacts. The report focuses on the space consumption of car traffic as opposed to on time losses from road congestion. It shows that by focusing on accessibility, user groups who would be most adversely affected by tolls can be identified and the effectiveness of mitigation measures tested.

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