FROM GIS-T TO URBAN TRANSPORT POLICIES: ACCESSIBILITY SIMULATIONS TO FAVOUR SUSTAINABLE MOBILITY

Yves CROZET, Laboratoire d'Economie des Transports, University of Lyon

Aurélie MERCIER, Laboratoire d'Economie des Transports, University of Lyon

Nicolas OVTRACHT, Laboratoire d'Economie des Transports, University of Lyon

ABSTRACT

This paper, presents a new tool to model and simulate transports policies using access-based indicators. This tool, namely a GIS coupled with a 4 steps transport model, is the result of MOSART program developed in LET (Lyon Institute of Transport Economics, University of Lyon). LET has developed the MOSART project (Modelling and simulating accessibility) to set up a tool to help in decision and town planning, allowing to study the accessibility of populations to services and jobs along the various networks (private car, public transport). After presenting some paradoxical results of accessibility measurement in relation with new public transit offers, the paper tests some public policies change like the set up of a urban toll or a high increase of mobility price due to a fuel tax or a sharp increase of fuel price. This kinf of "stress test" on urban mobility might prepare public policies to the effects of potential external shocks on accessibility and therefore on mobility.

INTRODUCTION

This paper, examining transport policy simulations, is considered as the third part of a thematic "trilogy" on accessibility composed by two other joined papers presented at the WCTR 2010. A first paper entitled *MOSART: an innovative modelling platform for planning sustainable mobility* (Mercier and *al.*, 2010) presents a new tool to model and simulate transports policies using access-based indicators.

This tool, namely a GIS, is the result of MOSART program developed in LET (Lyon Institute of Transport Economics, University of Lyon). LET has developed the MOSART project (Modelling and simulating accessibility) to set up a tool to help in decision and town planning, allowing to study the accessibility of populations to services and jobs along the various networks (private car, public transport). The objectives of the MOSART project were to develop this tool to:

- model and simulate the levels of services offered by the different transport networks (private car, public transport);
- study and analyse people's mobility,
- compare scenarios of transport policies and town planning in a sustainable development framework,
- set up an observatory of spatial accessibilities (through a web mapping).

This tool aims at providing accessibility indicators which can be the basis of mobility policies and town planning by introducing the accessibility concept at the heart of the reasoning. The main idea is to propose to inhabitants and urban users another view of urban mobility.

For instance, at the level of Lyon's urban area (296 local administrations – 3,316 square kilometres) we are setting up a web mapping tool which helps to define policies of public mobility and town planning, but also supports private choices in terms of location, transport means and itinerary. By using a very sophisticated traffic model, but also precise spatial databases, an interactive GIS and a powerful digital simulation, we are constructing for the Lyon's region, the prototype of what will be in coming years, the common management tools of persons and goods mobility.

Technical aspects and accessibility computations issues derived from MOSART are detailed in the second paper presented in Lisbon Confrence *Improving accessibility measurement combining transport modelling and GIS analysis: two examples from France and Germany* (Mercier and Stoiber, 2010). To make the reading easier, elementary technical elements on accessibility measures and main hypothesis are recalled in the "methodology" section (1). Then, we present some discussion about the sensitivity of accessibility measurement and some paradoxical results (2). We use then the MOSART tool to test some new public policies, a new Tramway line (3), cordon toll (4) and a fuel tax or a fuel extreme increase of price (5).

1. METHODOLOGY

Study area

The Lyon Metropolitan Area was chosen as a case study to implement accessibility simulations. One reason for selecting this area, excepted the availability of data and the "on-the-ground knowledge", refers to its dynamism allowed by its transport networks. The study area has been divided into 4,344 zones to perform access measures.

Job-access measurement

Gravity-based accessibility to jobs is measured for car users and public transport commuters, on the morning peak period. The following expression is considered (Hansen, 1959):

$$A_i = \sum_{j=1}^{n} E_j \exp^{(-\beta C_{ij})}$$

where E_j represents opportunities in zone j, C_{ij} denotes the travel cost (or generalized cost) between zones i and j, β represents cost sensitivity parameter and n the number of zones.

Opportunities are defined as the total number of jobs.
Travel costs is the algebraic sum of monetary costs and travel time costs:

- Monetary costs are distance-dependant. They refer to purchase, fuel and maintenance costs for cars users and to ticket price for public transport commuters.
- Travel time is computed using a "shortest path algorithm". Both travel time by car and by public transports integer road congestion level. Connection and waiting time are also considered for public transport trips. Parking costs are not included in car travel time. Travel times are weighted by a "value of time" of € 11.4 per hour, whatever the mode.

The sensitivity parameter is estimated by a calibration process to 0.18 for home-based work trips.

Job-access cartography reading

Two types of accessibility maps are presented:

1. Job-access index maps represent job-access level from every zone *i=1…4,344* to other ones. Gravity-based access results have no unit measures. Hence access-levels are not represented in absolute values but using an accessibility index (base 100 for the Part-Dieu area in the CBD).

2. Job-access variation maps illustrate either variation for a given mode between two "periods" either variation between two modes in a given "period". In this last illustration, red-zones represent an higher car-access level and blue-zones represent an higher public transport access level.

2. PARADOXICAL RESULTS IN ANALYSING EXISTING MODAL COMPETITION

The first step focuses on modal accessibility considering separately car and public transport access-results. As illustrated by Figure 1 access-level is decreasing from the Central Business District, whatever the mode considered. The main reason to explain this result could be heavily spatial concentration of jobs in CBD (with a job density higher than 10,000 per km²). Workers located within or closed to the CBD enjoy a lower travel time than workers living on suburban areas. For example, while a CBD's inhabitant has an access level higher than 60 by car and higher than 15 by public transports, a suburban-located worker has an access-level is lower than 30 by car and lower than 15 by public transports.

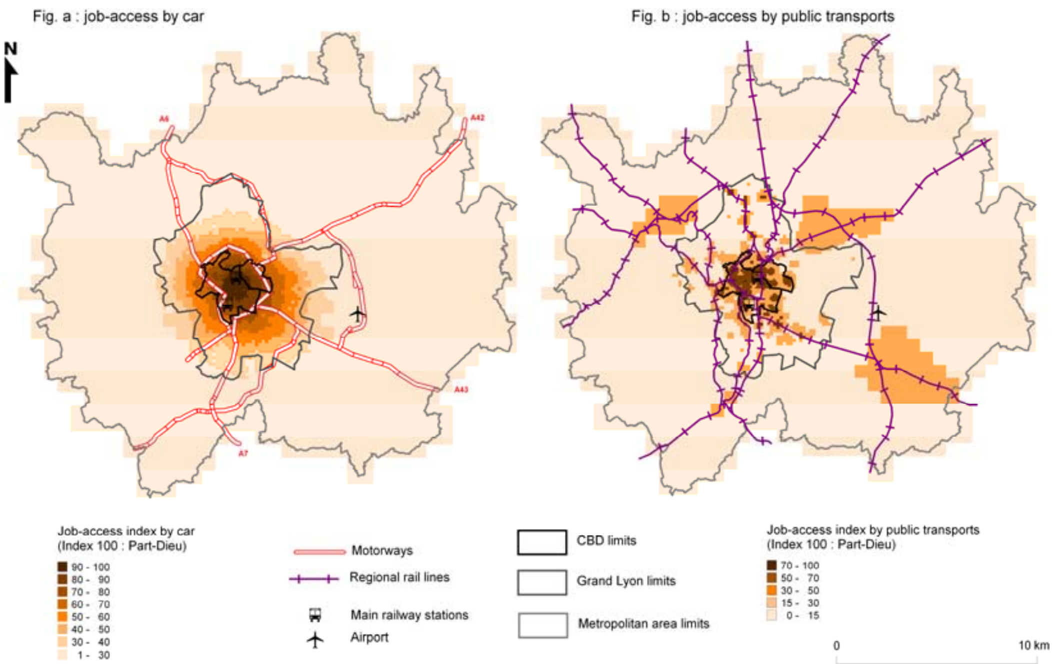

Figure 1 : Job-access by car (fig. a) and by public transports (fig. b)

Interesting access-structure differences can be observed comparing the two modes. Job-access by car is represented in a structure by concentric circles highlighting a very dense road network. Car-access level seems to depend more on the CDB distance than on motorway infrastructures. High-speed road infrastructures suffer first from congestion. Hence in peak hour, travel speeds on motorways are at the same level as speeds on other roads. As observed in a joined paper (Mercier and Stoiber, 2010), 30% of road sections with a free flow car speed higher than 110 km/h are saturated between 7 AM to 10 AM and 70% of them have a dense traffic. Job access-level by public transport is structured within "finger gloves". This representation suggests impacts of both urban public transport and regional public transport on access level. A high job-access level (index greater than 70) by public transports on the CBD is explained by efficient transport lines as subway lines (with a commercial speed between 16.5 km/h and 31 km/h and then a frequency between 5 minutes and 2 minutes). When coupled to bus lines in final trips, subway lines allow some area to reach a high job-access level. At the metropolitan scale, the intermodality between suburban public transport and urban public transport is a key element to a high job-access level. It is observed in Figure 1 (b) that suburban areas with an access level higher than 30 are served by local rail line, whatever their distance from the CBD. The example of the rail connection between Bourgoin and Lyon (on the Lyon metropolitan area south-eastern) is striking! On the morning peak-hour, rail frequency is every 10 minutes and travel time is estimated to 30 minutes. Rail trips are often intermodal trips and need a car use: it is assumed that rail users join the railway station by car (with an assumed speed to 50 km/h). Then rail users can finish their home-based work trip using urban public transports: each main railway station is connected to the sub-network.

At the metropolitan area scale, a great discrepancy between road users and public transport ones is illustrated by Figure 2. Impacts of transport policy on modal competition are unexpected and, to say the least, paradoxical. Job-access level is more than four time higher by car than by public transport. What is paradoxical is first the higher road performance in the CBD, well-served by an efficient public transport network. Higher car access-level can be explained by a dense road transport network on the whole study area while public transport networks serve only “communes” located on the Grand Lyon perimeter and on some other suburban areas. In spite of road congestion charges, car speed is often higher than public transports’ one. For example, speed under the Fourvière road tunnel (one of the most congested road link) estimated to 22 km/h is the same as subway speed.

The second paradox refers to the higher public transports performance in 5% of the metropolitan area. Figure 2 reveals that every zone concerned by this result is suburban and located outside the Grand Lyon perimeter. These zones have in common to be served by the regional rail network presenting public transport travel costs lower than road ones. Lower monetary costs by train allow to offset a slightly higher travel time.

The highest job access-level by car (than public transports) outside the Grand Lyon perimeter is not very surprising. Suburban areas are first served by a dense and efficient road network less congested than in the Grand Lyon perimeter. Second, only some suburban areas are connected to a public transport network (to be connected an micro-zone must be located either less than 500 meters from a urban public transport station or less than 10 kilometres from a railway station). Moreover, transport networks don’t serve the whole metropolitan area and speeds can be lesser than in road network.

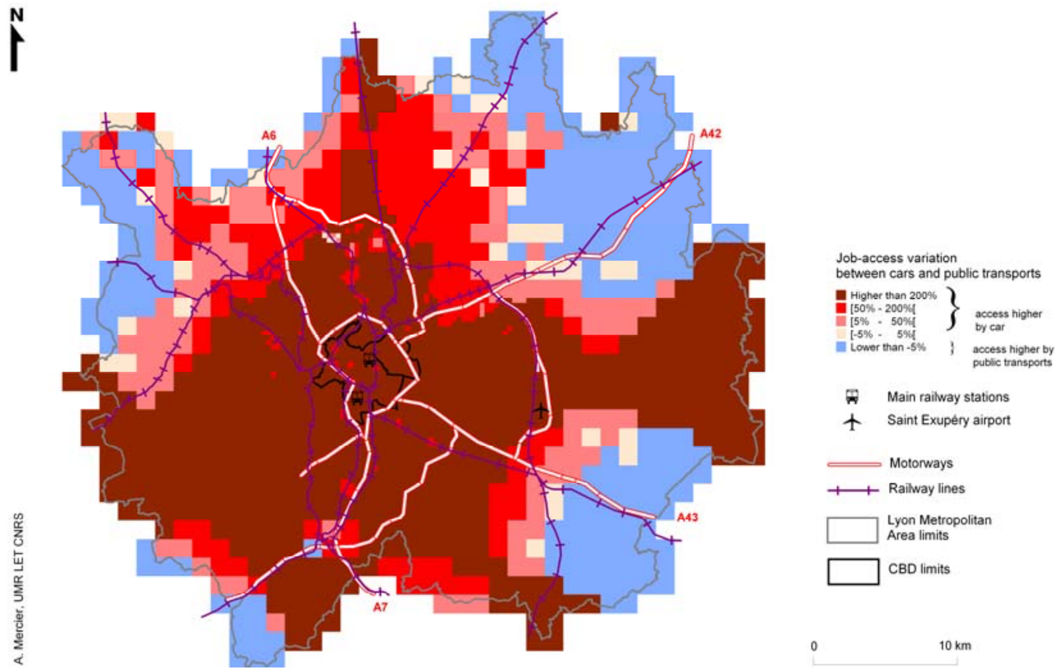

Figure 2 : Job-accessibility variation between car and public transport – Base situation

3. IMPACT OF A NEW PUBLIC TRANSPORT LINE ON ACCESS-LEVEL

T4 Tram-line presentation

The section simulates impacts of a tram-line implementation on public transport users' access level. It hence focuses on an urban quarter in the "commune" of Lyon and neither on the Metropolitan nor on the Grand Lyon area. The tram-line T4 was selected for its specificities in terms of objectives and location. This tram-line was opened in April 2009 to be a major urban public transport line serving the south-east part of Lyon. This 10-km line is entirely located in urban area on the "communes" of Lyon, Vénissieux and Feyzin. Along the T4 tram-line, 33,000 jobs and 6,200 inhabitants are located.

Serving 18 stations the tram-line T4 is connected both to the subway network and to the regional rail network (at the "Gare de Vénissieux" station). Two park and ride facilities are located along the tram route. The T4 tram-line implementation is followed by a bus network reorganization: more than 15 bus routes has been restructured to improve connections in the terminus « Jet d'Eau ».

The project's short term objective is a public transport access-level improvement with a high-speed connection from Vénissieux or Feyzin to Lyon (8th quarter). In long-term urban land-use aim is achieved rendering both the Etats-Unis and Minguettes quarters more dynamic. We assume the new tram-line has no impacts on jobs (number and location).

Public transport job-access results consistent with T4 tram-line objectives

According to the T4 tram-line objectives detailed previously, access-level is measured from the Etats-Unis quarter (located on the "commune" of Lyon), and from the Feyzin and Vénissieux "communes" to jobs located on Lyon and Villeurbanne "communes". A large job-access level variation, higher than 150%, is observed with the T4 tram-line implementation. As illustrated by Figure 3, access-level by public transports has increased by 50% at least for every area served by the tram-line. Increased tram commercial speeds and frequencies according to bus lines can first explain such a result. On the morning peak hour tram frequency and speed reach respectively 7 minutes and 20 km/h while 10 minutes and 14 km/h for the "old" bus line. Contrary to bus lines, a tram-line no suffers from road traffic congestion. Furthermore owing to the public transport network reorganization, and a connection system improvement between tram and subway lines, bus lines generate positive access-level variations too.

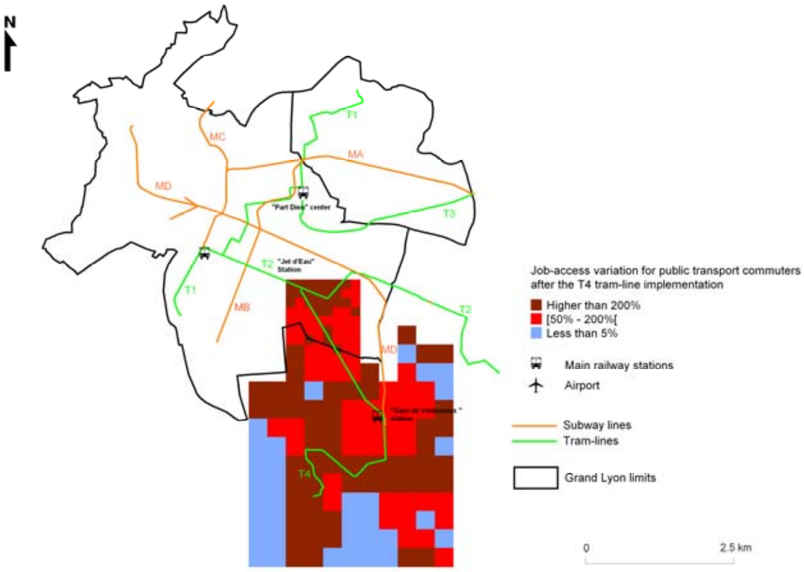

Figure 3 : Job-access variation for public transport commuters after the T4 tram-line implementation

It's interesting to note that positive job-access variation is relatively lower within a 500m-radius from the "Gare de Vénissieux" station than on the rest part of the area served by the tram-line. Because it was previously served by a subway line, this radius from the "Gare de Vénissieux" station gains only slight job-access variation with the tram-line implementation. Only accessibility to jobs located in the 8th quarter of Lyon (near the "Jet d'Eau" station) or near the "Part-Dieu" centre increased.

If Figure 3 reveals a positive job-access variation for almost zones, for some of them job-access level is smaller after the tram-line implementation. This decrease is not really due to the new tram-line but is mainly explained by the bus network reorganisation. According to changes in bus routes some areas are no more served by public transports. Areas affected by a job-access decrease are uninhabited and located in industrial parks.

How to explain such a craze for the T4 tram-line?

Right from the T4 implementation in spring 2009, the number of public transport users on this tram-line has been higher than estimations. How can the result be explained given that job-access level stays higher by road than by public transports despite the T4 tram-line (variation estimated to 113%)? Can we explain a high T4 line use by its comfort and reliability parameters? In other words, is there a tram-line "attractive coefficient" to explain such a level of use?

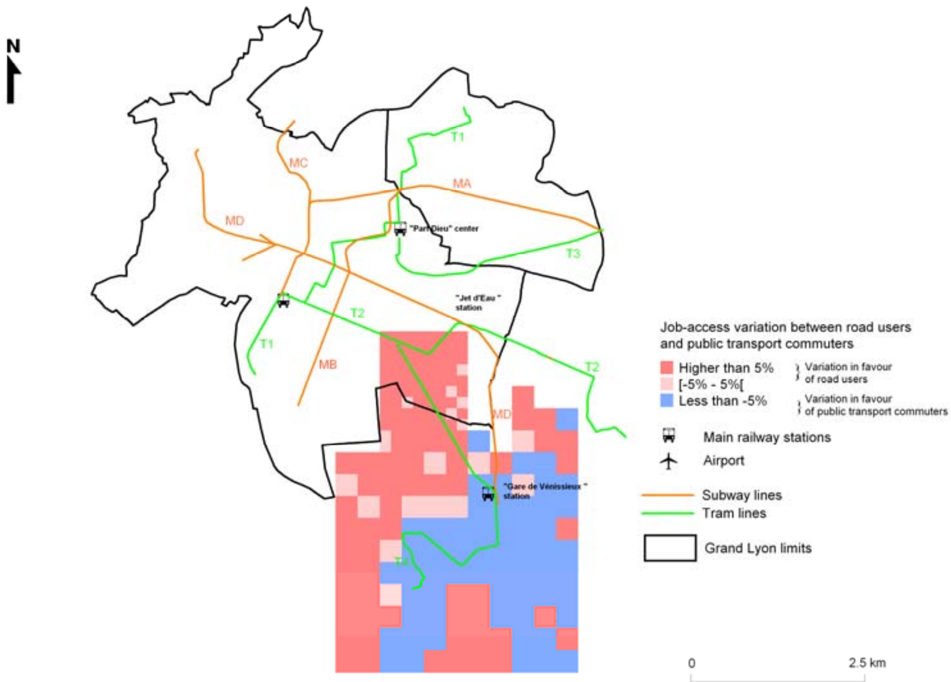

Figure 4 : Job-access variation between road users and public transport commuters with a perceived travel time to 25% of real travel time

The "four-step model" implementation within four transport modes (car, public transport, walking and two-wheeled vehicles) does not allow to distinguish car and tram travel time perception. Nevertheless an "attractive coefficient" between public transports and car can be implemented. Hence, the following question is asked: what is the level of travel time perception in public transport to equalize job-access levels by cars and by public transports? The simulation is realised considering job-access level from the Etats-Unis quarter (located on the "commune" of Lyon), and from the Feyzin and Vénissieux "communes" to jobs located on Lyon and Villeurbanne "communes". Given that tram-lines and subway are the two main modes used for such trips, public transports' "attractive coefficient" refers in fact mainly to trams and subways.

Public transports' "attractive coefficient" is estimated to 25% of real travel time by public transport. To equalize job-access level by car and by public transport, travel time by public transports should be perceived at 25% of its real level. It seems to be impossible to obtain such a result in "real life" because of huge comfort and reliability costs (Coindet, 1999). Figure 4 reveals that a perceived travel time decrease impacts mainly areas served by the south part of the T4 tram-line. In these zones job-access level becomes higher by public transports than by car. A perceived travel time decrease coupled to comfort and reliability parameters are all the more important since travel time is high. In the North and West parts of the studied area, job-access stay slightly higher by car. Relatively low travel times to access jobs in base situation can explain a slight impact of a perceived travel time decrease on access-level.

4. WHAT HAPPENS IF A URBAN TOLL IS IMPLEMENTED?

Urban toll presentation

In the context of road space and public money scarcity in urban areas as environmental constraints, road tolls are applied as a method of regulation in the transport system (Raux and Souche, 2003). Introducing a car tax to road users, an urban toll can be seen as a first solution to reduce road consumption and environmental impacts.

This section examines an urban toll simulation on Lyon both to analyse impact of new financial constraints on modal shares and on job-access levels. A urban toll is seen as a price signal sent to road users: those who have a willingness to pay inferior to the urban toll cost would stop to use charged road sections. Hence, travel time would be better for other road users.

Different types of urban tolls are operated (toll cordons, infrastructure-based tolls, zonal-based tolls) according to a various set of objectives (transport infrastructures financing, road traffic control and environmental protection…). Following traffic flow regulation objective under environmental constraint, a toll cordon is introduced all around the CBD (a 62 km² area corresponding to the Lyon and Villeurbanne “communes”), considered as the main employment area. A fee of € 3 is charged to travel to Lyon or Villeurbanne (whatever the origin of trips and the time of the day). This toll price is relatively low to affect most of road users and not encourage them to transfer to another route or another mode. Nevertheless a too low price wouldn’t send a real price signal to road users. Considering a value of time of € 11.4 per hour, a € 3 toll price can be compensated by a travel time gain estimated to 16 minutes. Note that toll price is integrated on the 4 step model (presented in Mercier and Stoiber, 2010) to affect mode choice and traffic assignment.

Impacts of urban toll on job-access by car

The effect of a toll cordon operation is a low car job-access decrease of 5%. This drop in access level by car can be differentiated according to zones location. As illustrated by Figure 5 a), the Lyon metropolitan area can be divided into three parts according to their distance to the CBD:

- In the CBD and inner suburbs: job-access by car decrease is estimated between 10% and 20% in the CBD and between 5% and 10% in inner suburbs. Note few exceptions with areas located near the skirting round.
- In outer suburbs located on the Grand Lyon, job-access level remains stable

- In outer suburbs located on the Lyon metropolitan area, job-access level by car is increasing with the urban toll implementation. Job-access rise is higher than 10%.

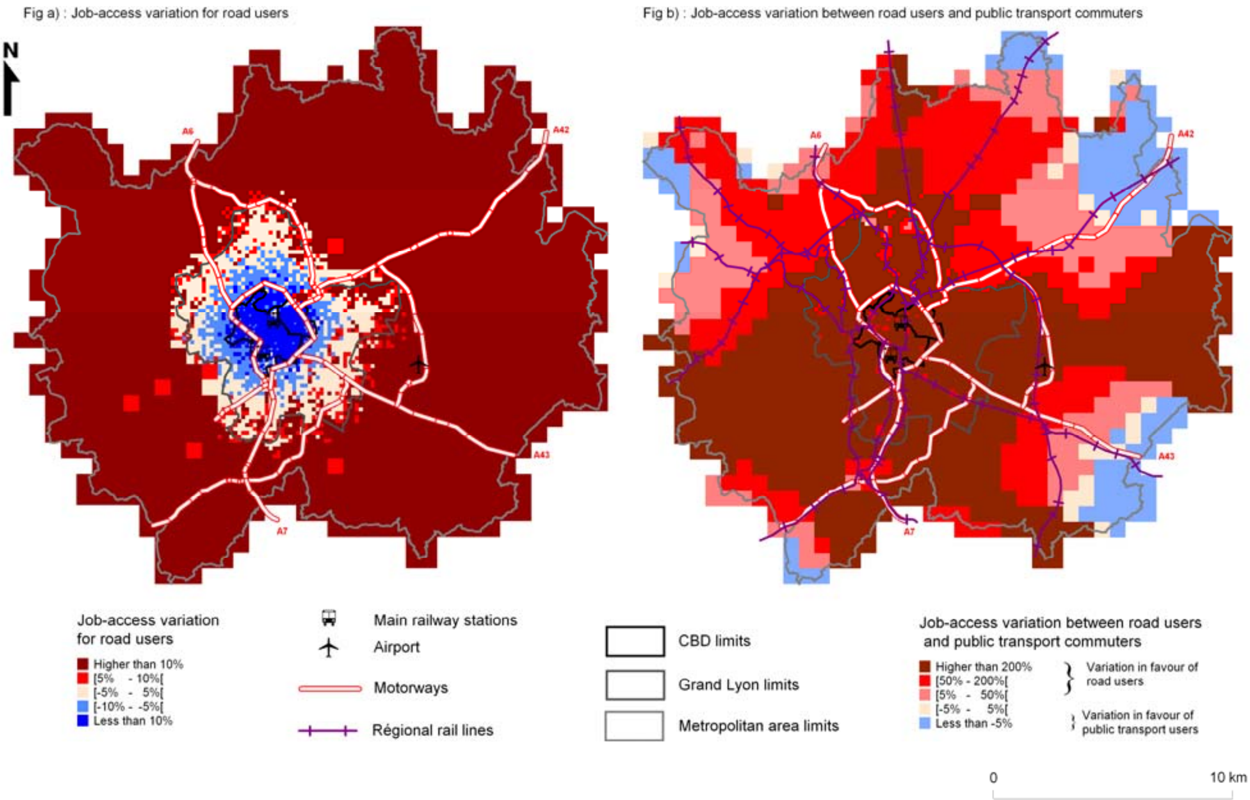

Figure 5 : Job-access variation for road users and between road users and public transport commuters

There are many reasons to explain this striking difference between zones in car job-access variation. Firstly travel time from area located inside the CBD is the lesser to access the whole metropolitan area and the most of jobs. Therefore considering internal trips to the CBD (with a mean distance lesser than 7 kilometers and a mean travel time lesser than 12 minutes), a urban toll amounted to € 3 (equivalent to a travel time increase of 16 minutes) increases generalized transport cost by 37%. An urban toll implementation does not generates a car traffic decrease sufficient to reduce travel time and therefore to compensate toll monetary costs. Secondly, low impacts of a cordon toll in the Grand Lyon perimeter can be explained by the trips cost structure. Urban toll cost makes up a lower part of the generalized cost for trips from outer suburbs on the Grand Lyon to the CBD than for internal CBD trips. Hence, job-access level by car is not greatly affected by a toll cost increase. Thirdly, the job-access increase in outer suburbs located on the Lyon metropolitan area can be striking! How can a new transport tax increase the access-level? This question can be answered in three different ways:

1/ As previously, the toll share on the generalized transport cost for trips to CBD is lower from outer suburbs than from the CBD. Therefore access-level is less impacted for a 15-km trip than for a 7-km trip. Nevertheless if urban toll slightly increase transport cost, it cannot allow decreasing monetary charges.

2/ Transport cost decrease refers to a travel time improvement. The urban toll implementation has contributed to a new modal distribution. Table 1 presents modal shares resulting from the car tax. When considering an urban toll implementation, number of car trips in peak period decreases from 48% to 44%. Car transport demand has been only transferred to two-wheels modes reaching a modal share of 25%.

	Base situation	**Urban toll**
Car	48%	44%
Public transports	19%	18%
Walking	13%	13%
Two-wheels modes	20%	25%
Total	100%	100%

Table 1 : Modal shift

Road traffic analysis highlights that road sections with a high car traffic decrease are located outside the Grand Lyon. Therefore travel time improvements affect mainly trips from outer suburbs located on the Lyon metropolitan area. For these trips, the urban toll implementation allows a generalized transport cost decrease of 25%. Speed increase on motorways also impacts job-access level of zones located near motorways A7 (south of Lyon), A43 (south-east), A42 (north-east) which have a car access-variation of 10%.

The example of outer suburbs highlights a widely impact of monetary and travel costs on access-levels. Nevertheless caution is advised in results interpretation. Job-access impacts of urban toll don't have to be overestimated. In spite their positive access-level variation, access-level in base situation are very low in outer suburbs (with access-index inferior to 30). A generalized cost decrease impact on access-level is all the more important since access-level is low.

Urban toll and modal competition

Urban toll allows to reduce job-access variation between car and public transport users. Considering the whole study area, job-access variation between the two modes is estimated to 430% (and 460% in base situation) in favour of car users. Figure 5 b) illustrates this result with a concentric circle structure (as previously in Figure 2). In both situations, job-access level is better by car than by public transport for 90% of the study area. The urban toll implementation and resulting travel time improvements tend to reduce public transport access-level. While job-access level is higher by public transports in 5% of zones in base situation, it is higher in 2% of zones with an urban toll. Only the boarder located areas have an access-level higher by public transports in both situations.

An urban toll implementation on the CBD perimeter cannot reverse modal competition. In spite of a cordon toll, the higher transport cost for road users is compensated by a lower travel time. Following the main urban toll objective, car users staying on the road network in spite of an urban toll benefit from lower travel times but have to pay the full price.

5. WHAT HAPPENS IF A FUEL TAX IS IMPLEMENTED?

A carbon tax

A first tax simulation refers on the carbon tax which should have been implemented in France on the 1st January 2010. This tax aimed to tax gas, oil and coal consumption to encourage households and firms to change their consumption behaviours. Set to € 17 per ton of carbon dioxide, this tax can be seen as a fuel tax of € 0.045 per litre. Considering a car fuel consumption of approximately 4.9 litres per hundred kilometres and a fuel cost (before the carbon tax) of € 6.45 per hundred kilometres, carbon tax does not impact really mean cost per kilometre which remains stable to € 0.49 per kilometre (mean cost refers to the sum of buying, financial, insurance, fuel, maintenance and parking costs). Marginal cost (including fuel and maintenance costs) slightly increases from € 0.14 to € 0.15. Monetary and time costs remaining stable despite the fuel tax, job-access level by car don't vary according to the base situation. Carbon tax isn't too high to impact access results; a new "extreme" tax is simulated.

An "extreme" fuel tax

The objective of this "extreme" tax is to double fuel price per litre according to the maximum price (€ 1.3 per litre) observed in June 2008. The extreme tax is set to reach € 3 per fuel litre. Such a fuel price generates a mean monetary cost of € 0.58 (increase of 18% according to base situation) per kilometre and a marginal cost of € 0.23 per kilometre (increase of 64% according to base situation). A restrictive hypothesis considers the fuel tax does not impact, in a first time, car user behaviours: car users don't take into account the higher fuel cost in modal choice and don't decrease their trip length.

Impact of this extreme tax on job-access variation between car users and public transport users is illustrated by Figure 6. Job-access variation for car users is not examined: this extreme tax impacting every road trips proportionally to the distance, access variation is not relevant to analyse. Cartographic representation of job-access variation between modes is like to the base situation one (illustrated by Figure 2). Nevertheless it reflects a job-access decrease by car: job-access variation is estimated to 4.14% in favour of car users while 460% in base situation. Areas where tax impact is the highest are located in outer suburbs on the Lyon metropolitan area, mainly on northeast and northwest. For them a high fuel cost increase generates a job access-level higher by public transports than by cars. An efficient regional rail network, characterized in peak hour by high commercial speeds and frequencies, explains this result. Nevertheless and despite an extreme fuel tax, for 90% of zones job-access level is higher by car than by public transports.

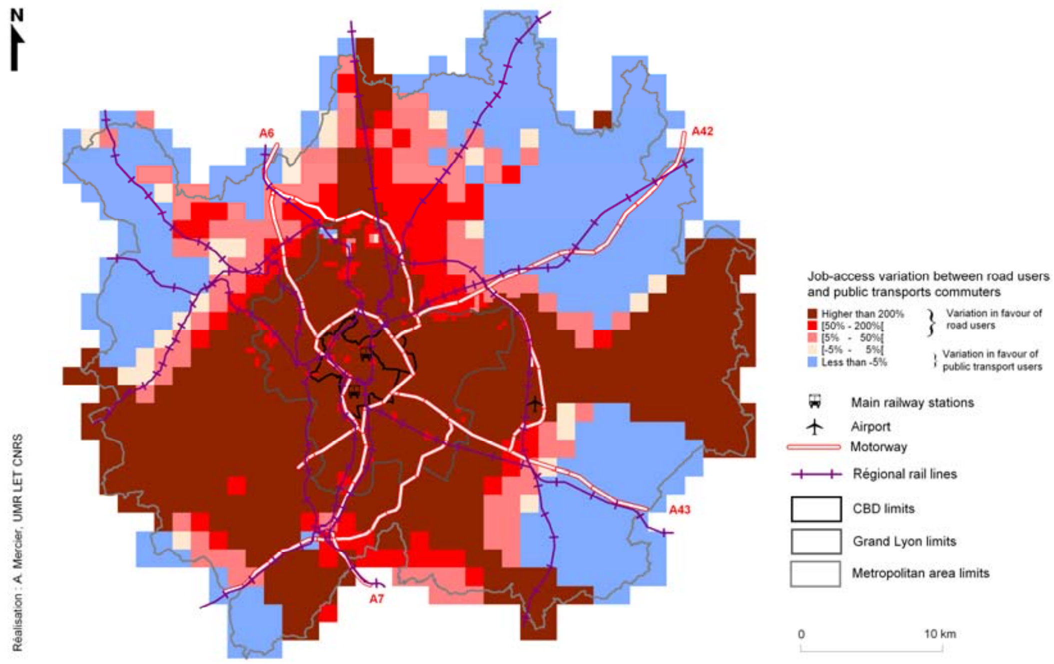

Figure 6 : Job-access variation between roads users and public transport commuters

It is often observed, whatever the tax (cordon toll or fuel tax) considered, that zones where job-access level is higher by public transports are located outside the Grand Lyon. How can this result be explained, given that the Grand Lyon is served by an efficient public transport network? Beyond trip cost structure which does not integer parking costs (neither monetary component nor time costs), both the urban public transport structure and the study area perimeter can explain this result. The Lyon metropolitan area is stretched beyond the urban public transport perimeter and the trip range is often higher than area served by urban public transports. More than 60% of total trips from the CBD cannot be fully made by collective transports. Furthermore and despite congestion, travel speeds by cars are generally at least equal to speed by public transports. As illustrated by Crozet (2009), a study area restricted to the Grand Lyon perimeter should have concluded to an access-level higher by public transports in the CBD.

6. CONCLUSION

According to statisticians, 2009 was the year during which the threshold of 50% of inhabitants living in cities has been crossed. This phenomenon is not surprising. Contrary to the romantic lie that makes us believe that we are happier in the countryside, it is the city which attracts. It is more capable of offering jobs and various public services and amenities. This relative attractiveness of the city is at the source of its success and its difficulties in maintaining the human flow, its concentration and its distribution in space. To face these issues, transport systems and their improvements were part of the answer, with tangible results in terms of improvement in attractiveness and hence in relative worsening of accessibility problems (road congestion, overcrowding of public transport, trend of urban dispersion). In front of such an escalation mechanism, there is no panacea, no simple solution which could definitely solve the issue. It is however possible, by using the accessibility rationale, first to understand why a choice is better than the other for the community and then how it is possible to combine general interest and individual interests in the prospect of sustainable mobility. It is not the least of the paradox of the accessibility concept to offer, through some convenient model like MOSART, to test the effects of diverse public policies. Some decades ago the attempts to increase average speed on road, and now, due to environmental constraints, to test the impacts of a higher cost of mobility.

BIBLIOGRAPHY

Ben-Akiva M, Lerman S., 1985. Discrete choice analysis: Theory and Application to Travel Demand. MIT Press, Cambridge, MA.

Ben-Akiva M, Lerman S., Disagregate travel and mobility choice models and measures of accessibility. In Hensher, D.A., Stopher, P.R. (eds), *Behavioural travel modelling*, Croom Helm, London, 1979, pp. 698-710.

Bonnafous A., Masson S., « Evaluation des politiques de transports et équité spatiale », *Revue d'Economie Régionale et Urbaine,* n°4, 2003, pp. 547-572.

Burrough P.A., McDonnell R.A., *Principals of Geographical Information Systems*, Oxford University Press, 1998

Crozet Y., "Economic Development and the Role of Travel Time: the Key Concept of accessibility", Commissioned paper for the 2009 VREF (Volvo research and education foundation) Conference on Future of Urban Transport: Looking for an Architecture for a Sustainable Urban Transport, Gothenburg, April 20-21, 2009, 23 pages.

Crozet Y. *Strategic issues for the Future Fundings and Operation of Urban Public Transport Systems*, in « Infrastructure to 2030, Volume 2, Mapping Policy For Electricty, Water and Transport », OECD publishing, 2007, pp. 413-462

Crozet Y*., Time and Passengers Transport*, 127ème Round Table of ECMT, Le temps et les transports *,* OECD, Paris, 2005, pp. 27-69

Department For Transport (2004). Measuring Accessibility for the Appraisal of Wider Economic Impacts, TAG Unit 3.5.11, 7p.

Dong X, Ben-Akiva M., Bowman J., Walker J., « Moving From Trip-Based to Activity-Based Measures of Accessibility », *Transportation Research A*, Vol. 2, 2006, p. 163-180.

Geurs K.T., van Wee, B. (2004): Accessibility evaluation of land-use and transport strategies : review and research directions", *Journal of Transport Geography*, vol.12, p127-140

Hansen W.G., « How accessibility shapes land use », *Journal of the American Institute of Planners,* 25, 1959, p. 73-76.

He Kebin & Chang Cheng, Present and Future Pollution from Urban Transport in China, China Environment Series n°3, Washington D.C.: The Woodrow Wilson Center (2000).

Koenig J.G., « Indicators of urban accessibility: theory and application ». *Transportation.* 9, 1980, pp 145-172.

Kwan, M., 1998. Space–time and integral measures of individual accessibility: a comparative analysis using a pointbased framework. Geographical Analysis 30 (3), 191–216.

L'Hostis, Aa.; Wulfhorst, G. (2006). Travel Demand Management by accessibility planning and location choice. European Transport Conference 2006, Strasbourg

Mackett R., Towards the solution of Urban Transport Problems in China, Journal of Environmental Sciences, Vol 11, n°3, 1999, pp. 334-338

Mercier, A.; Stoiber, T. (2010): Improving accessibility measurement combing transport modelling and GIS analysis: two examples from France and Germany. Paper presented at the WCTR Lissabon, 11-15/07/2010

Miller, H.J. (1999) Measuring Space-Time Accessibility Benefits Within Transportation Networks: Basic Theory and Computational Procedures. *Geographical Analysis*, vol 3, pp. 187-212.

Mogridge M.J.H., Travel in Towns: Jam Yesterday, Jam Today, Jam To Morrow? London, 1980, McMillan

Morris J.M.., Dumble P.L., Wigan M.R. (1978). Accessibility indicators for transport planning, *Transportation research A,* pp. 91-109.

Neuburger H., « User benefit in the evaluation of transport and land use plans », *Journal of Transport Economics and Policy*, 5, 1971, p. 52-75.

Small K.A., Rosen H.S., « Applied Welfare Economics with Discrete Choice Models », *Econometrica*, vol. 49, n°1, 1981, 105-130.

Wulfhorst, G. (2007): Systems Thinking approaches for the integration of land-use and transport – From railway station development to accessibility planning in urban regions. Conference Paper presented at the World Conference on Transport Research, University of California, Berkeley, June 2007

Wulfhorst, G.; Stoiber, T. (2009): Accessibility planning in a railway corridor in Frankfurt/Rhein-Main region); contribution to the NECTAR workshop cluster 6 „accessibility“; Pula-Cagliari

Zahavi Y. & A.Talvitie, 1980, Regularities in Travel Time and Money, Transportation Research Record 750, p.13-19.