# MOSART: AN INNOVATIVE MODELLING PLATFORM FOR PLANNING SUSTAINABLE MOBILITY

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## ABSTRACT

In the context of spatial and environmental constraints coupled to a need for dynamic transport/land used analysis, the paper presents the innovative modelling platform "MOSART". In a first version, MOSART has been implemented as a Geographical Information Systems in Transportation producing accessibility analysis. It has been moved to an innovative modelling platform for planning sustainable mobility introducing gravity-based analysis in a second version. Combining analysis on both urban speed issues and land-use patterns from an access-based point of view, MOSART presents a new approach of transport and land-use polices assessment.

Keywords : Accessibility, Geographical Information Systems for Transportation, Transport modelling.

## INTRODUCTION

In France, like in many other countries, urban road congestion hasn't stopped growing since the seventies and the massive use of the automobile. While road infrastructure constructions were favoured to answer congestion during last decades, transportation planners tend now to counterbalance the need of high travel speed with public transport infrastructures and two-wheeled modes development. The implementation of tram-lines in 19 cities in France since the nineties (before 1990, only three cities were served by tram-line) illustrates this new transportation strategy aiming not only at reducing both road congestion and pollution but also reorganizing urban structure.
The structure and capacity of urban transportation network directly affects the level of accessibility (Zhu and Liu, 2004). The concept of accessibility, introduced by Hansen in

1959, can be common defined as the ease with which activities may be reached from specific locations and using a particular transportation system (Morris and *al.*, 1978). Literature develops many specific definitions of accessibility according to different points of view (see Geurs and Wee, 2004 for a detailed review). Closely related both to the transportation system and the land-use patterns, accessibility derived from a transportation network influences urban structure. It hence impacts on land use and transport policies. In this context of increasingly constrained $CO_2$ emissions coupled to higher travel demand, access indicators appear as an interesting tool in the planning process. Accessibility allows to understand actual real transport and environmental issues and to simulate possible future constraints.

Considering both spatial and environmental constraints and the need for dynamic transport/land use analysis, the “Laboratoire d'Economie des Transports”, with the GEOMOD company partner, has been implemented the MOSART project since 2005. MOSART, a French acronym to MOdelling and Simulation of Accessibility to Networks and Territories (MOdélisation et Simulation de l'Accessibilité aux Réseaux et aux Territoires), is a decision making tool in terms of mobility for private and public authorities. This project “in progress” has three main final objectives:

- Modelling and simulating transport policies considering various networks (road, urban or interurban public transports networks…),
- Comparing different transport policy and urban planning scenarios,
- Presenting cartographic results with a web-mapping tool and a web-site.

From its construction and objectives, MOSART is mainly an independent accessibility-based project but it plays also a leading role on various transport, land-use or environmental based projects (such as PLAINSUDD, TILT…) developed on the “Laboratoire d'Economie des Transports”. This paper presents the MOSART project insisting on its different strata and various types of outputs produced. Considering the Lyon Metropolitan Area the paper examines how relationship between MOSART components allows to model transport and urban policies. As the years go back, MOSART has moved from a Geographical Information Systems in Transportation producing accessibility analysis (MOSART “version 1”) to an innovative modelling platform for planning sustainable mobility introducing gravity-based analysis (MOSART “version 2”). Note that this paper examining MOSART architecture must be considered with two other joined papers presented at the WCTR 2010. Technical aspects and accessibility computations issues derived from MOSART are explained in *Improving accessibility measurement combining transport modelling and GIS analysis: two examples from France and Germany* (Mercier and Stoiber, 2010). Transport policy simulations from MOSART are developed in *Accessibility simulations to favour sustainable mobility* (Crozet and *al.*, 2010).

# MOSART "VERSION 1": AN INNOVATIVE GIS-T

## Case study presentation

The Lyon Metropolitan Area was chosen as a case study to implement the MOSART project. In France the term of "urban area" would be more appropriated than "metropolitan area" (referring the official INSEE definition, an urban area encompasses an area of built-up growth and its commuter belt) but at the international level "metropolitan area" presents a similar definition as the French "urban area".

Geographical scale and spatial effects are particularly important for accessibility measurement. As shown by Kwan and Weber in 2008, urban research focuses on two particular scales. Regional scale considers effects of urban structure evolution into polycentric cities with a main regional centre attracting employment and shopping trips. The local level refers to the city centre and neighbourhood individual travel behaviours. Regional and local scales reflect different types of amenities and transport land-use interactions. Developed at the Lyon Metropolitan Area scale, MOSART can be used both on regional analysis and local one focussing only on the city centre.

The Lyon Metropolitan area, located in the south-east part of France, is the second highest area (behind Paris). It covers more than 3 356 km² and contains 296 "communes" (the smallest administrative subdivision in France) spread out over 4 districts (Rhône, Ain, Isère and Loire). A briefly division of the metropolitan area is as follow: the "communes" of Lyon and Villeurbanne on the center of the area are the Central Business District (CBD), their nearest suburbs are "communes" included in the Grand Lyon perimeter and then suburban "communes". The area has a population of 1.7 millions metropolitan people (INSEE, 1999 Census), and a population density of 508 inhabitants per km².

*Population growth is important (0.8% per year for 1999 – 2005, INSEE) and higher than in any other French Metropolitan regions (Paris, Marseille, Lille). As shown on*
Figure 1 population tends to be concentrated on central zones (in Lyon and Villeurbanne) and on their outlying "communes" in the Grand Lyon with densities higher than 750 inhabitants per km². Outside the Grand Lyon some dense "communes" are located close to motorway infrastructures.

The Lyon Metropolitan Area offers more than 800 000 jobs (in 1999) for 765 000 workers living in the area. In Lyon as well as in most European cities, the spatial pattern of population and jobs is almost similar: employment density is the highest in the city centre, with more than 10,000 jobs per km² in some CBD divisions. Indeed 42% and 82% of jobs are respectively located in the CBD and in the Grand Lyon, 75% and 34% of inhabitants are.

More than its dynamism, another specificity of the Lyon Metropolitan Area refers to its transport networks. Firstly Lyon is served by a well-developed motorway network linking North to South of France. The four main motorways link Chambéry and Grenoble (A43), Genève (A42), Saint-Etienne and Marseille (A7) and Paris (A6) from Lyon. A ring road has been implemented to bypass the CBD. High-speed rail lines from Lyon (to Paris or Marseille, for example) are coupled to a more and more dense and efficient regional rail network (rail lines have been improved and rail connections have been increased). Lyon has the second highest urban public transport network in terms of users and total length. This network is being continually improved with new bus lines, tram lines implementations or sub-line extensions. In 2010, the urban public transport network is made of 4 subway-lines (total length 29.3 km), 2 funicular lines (total length 1.2 km), 4 tram-lines (total length 49.1 km), 2 trolleybus lines and 133 bus lines for a total network length of about 1.035 km. These characteristics, coupled to an increase of public transport use by 9% between 1999 and 2006, highlight the high level of performance of urban public transports in Lyon.

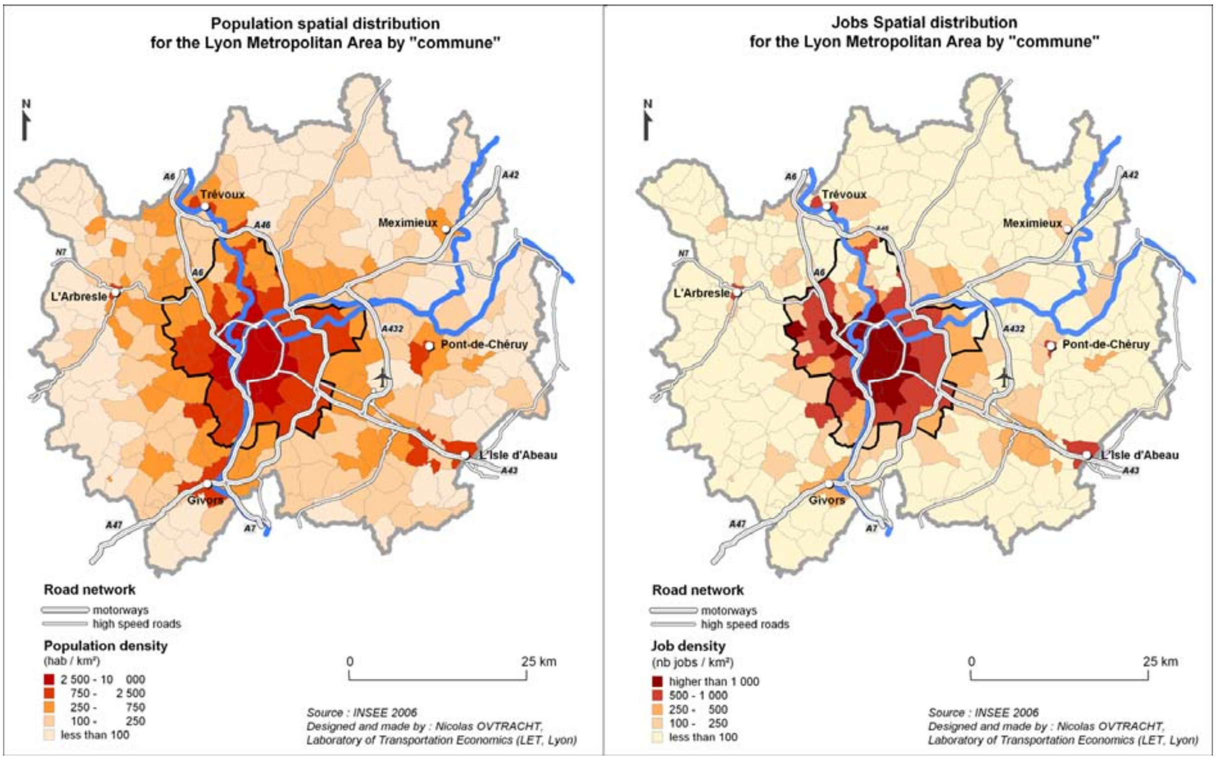


*Figure 1: Spatial distribution of population and jobs on the Lyon Metropolitan Area in 2006*

## GIS-T construction and databases

Transport and land-use represent two main applications of GIS (Longley and *al.*, 2005). As defined by Thill (2000), GIS in transportation is more than just one domain of application of generic GIS functionality. GIS-T has several data modelling, data manipulation; and data analysis requirement that are not fulfilled by conventional GIS. GIS-T has a central object of study, namely, the transportation network in a study area (Miller and Shaw, 2001)

In the MOSART GIS-T, three functional groups can be identified:

- Data collection derived from screen digitalization or data importation (represented in yellow )
- Data management refers to storage (represented in orange)
- Data analysis aims to produce time-access measures illustrated by cartographic results.

The SIS GIS software (Cadcorp) has been used to implement MOSART "Version 1". A number of databases should be available for use in GIS-T applications including transport networks, land use, socio-economic and demographic databases.

### *Road transport network modeling*

The road network obtained from the database NAVTEQ is integrated in the GIS. It is composed by more than 90,000 nodes and 220,000 links. A road section typology has been implemented using MYSQL to characterise each link by length, capacity, a maximum speed, the type of zone served (urban or non-urban areas) and driving direction or one-way streets. According to these different characteristics a classification into 15 road types is implemented. Such a typology can be easily updated and duplicated.

### *Urban public transport network modelling*

This database is created using topological methods from GIS. Each public transport line is created as "topological chain" composed by different "topological links". A public transport section can be run by many bus lines whatever the direction. Public transport attribute database has been integrated: each line is characterized by its different stations, a commercial speed and a frequency. Each connexion zones has been modelled and a walking time based on a 4 km/h speed is considered between two stations. This first public transport database is composed by 100 bus-lines, 4 subway lines and 3 tram-lines.
An application is developed by the partner company "Geomod" to improve shortest path analysis using a maximum credit time. Results are presented by Figure 2.

### *Integration of city bike stations (Velo'V stations)*

A system of self-service bicycles called Velo'V was set up in 2006. After paying a very limited yearly registration, a bicycle can be hired at any Velo'V station. Rental costs are as follows: the first thirty minutes of use are free and after every hour of use costs 1 euro. The GIS integrates the 340 Velo'V stations mainly spread over the cities of Lyon and Villeurbanne.

### *Socio-economic and land-use data*

Socio-economic data have been integrated according to various spatial divisions in order to perform spatial analysis. The "commune" is the largest geographical level, then the IRIS level is a "commune" division into areas of 2,000 inhabitants.
Population and main socio-economic data were obtained from the 1999 and 2006 Census (by INSEE) at the "commune" and Iris levels. However some socio-economic data are not in the public domain (number of shops and other facilities, for example) or not available at the IRIS level (number and structure of jobs, for example). In this context, not only national institute of statistic (INSEE) data have been integrated but different other sources have also been used.

Many databases are used to land-use analysis. While the Corine Land Cover 2000 refers to environmental landscape, the NAVTEQ database highlights mainly urban areas, industrial, natural zones.
A relational database model is used for the storage of socio-economic and land-use attributes. PostGis was preferred to Oracle Locator, Oracle Spatial and MySQL. Developed as a project in open source spatial technology, PostGis allows for user interface tools, basic topology support, and data validation. It is more certified by the Open Geospatial Consortium as compliant with the "Types and Functions" profile.

### *Data quality control*

A set of data quality verification have been implemented to improve spatial data quality. For example, the NAVTEQ database was compared to an orthophoto with a spatial resolution of 50 cm. New links have been created when necessary.

## Time-based access results

Analysing impacts of a transportation system on accessibility is one of the main “research fields” of MOSART (Crozet, Marchal and *al.*, 2008). In a first version, MOSART focuses on a “time-budget” approach with “isochronal” access measures. Isochrones count the number of opportunities that can be reached within a given travel time, distance or costs (Pirie, 1979). They can also measure the time or cost required to access a fixed number of opportunities (Geurs and Wee, 2004). This approach considers transport network performances. Travel times are computed using a shortest path algorithm.
The case of a new tram-line (called “T3 LEA/LESLY”) on the south-east of the CBD tram-line associated to city bike stations (Velo’v) is analysed focusing on the CBD. Figure 2 illustrates areas reached in 40 minutes (from Meyzieu) by urban public transports. Areas that could be reached in 40 minutes before the new tram-line implementation are grey hatched. Only Vaux-en-Velin or the outskirts of Villeurbanne (in the CBD) are. Using the new tram-line all areas in green can be reached by public transports. Tram is not a very rapid mode (18 to 20 kilometres per hour at commercial speed), but it is not affected by the road congestion at peak hour. Moreover owing to the tram-line connection with the sub network, it is possible to reach the CBD, and high job opportunities, within 40 minutes by public transports.

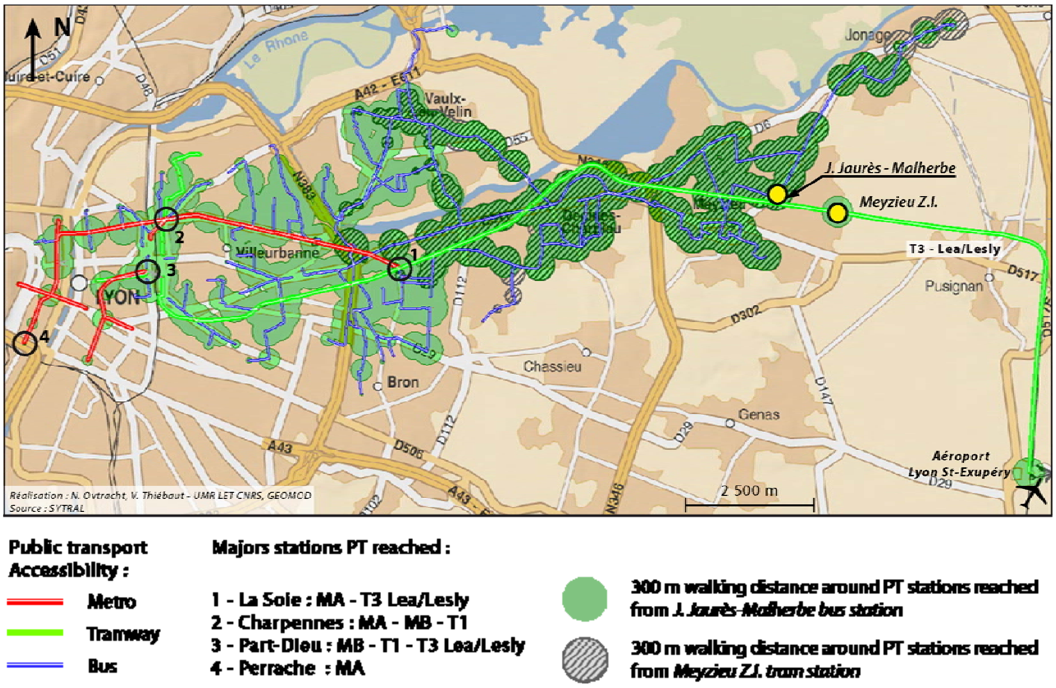


*Figure 2: Accessibility by Public Transport with a budget time of 40 minutes from Meyzieu (J. Jaurès Malherbe or Meyzieu Z.I.)*

If public transports are coupled to city bikes, areas reached in 40 minutes are red-hatched in Figure 3. Although the bicycle is a slow transportation means (average of 12 kilometres per hour), it significantly increases the accessible zone, by allowing access to areas relatively far away from subway stations.

Isochronal accessibility maps are of further interest as they also underline the evolution of the situation compared to attractive opportunities of an area, in particular the number of inhabitants, shops and jobs. While moving from using only bus to using tramway and subway, the accessible area doubles, but the number of jobs is multiplied by 8 and even 11 when adding the use of self-service bicycle. The multiplying factors (inferior to 5) are slightly lower for the accessibility to population and to shops, but they are still significant. Such results are obviously linked to the high population, shops and jobs density in the central part of Lyon. If relatively slow transportation means such as the tramway and bicycle face such a success, it is mainly because they are set up in such dense areas.

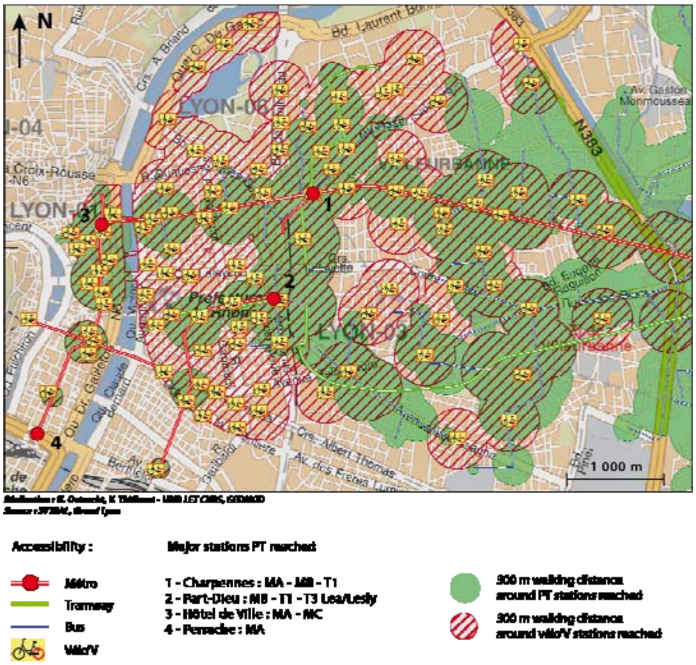


*Figure 3: CBD areas accessible in 40 minutes (PT + Vélo'V) from Meyzieu*

## MOSART "VERSION 2": AN INNOVATIVE MODELLING PLATFORM OF URBAN SIMULATION

Considering high potential of MOSART "version 1", it was decided to pass an important milestone introducing MOSART "version 2". In this second version, MOSART is no more a GIS-T but also a real innovative modelling platform of urban simulation. For that, we are coupling a transportation model with a GIS. Following Miller (2001) "*instead of "reinventing the wheel" within a GIS, often a better strategy is to integrate the GIS with another software with analytical tools tailored for a particular domain. This allows complementary linkages between general-purpose geographic information processing tools and special-purpose tools"*. Goodchild presents three alternatives to coupling GIS with spatial data analysis tool (Goodchild, 1992), going from a weak to a strong linkage. The loose coupling approach is just an import and export data function between applications. Conversely in the full integration approach, there is no distinction between the two applications. This approach embeds spatial analysis procedures fully within a GIS environment. The close coupling approach is an intermediate approach.

The ambitious MOSART project "version 2", with an integrated GIS approach, aims to be in the tradition of Land-Use and Transport Interaction models (see Wegener, 2004 for a detailed overview of Land-Use Transport Models) and to combine three innovative aspects:

- Two static road traffic assignment, one for peak and one for off-peak period, using the VISUM software (PTV)
- An introduction of a detailed spatial analysis based on precise land-use data and transport networks
- A GIS coupled to a web-mapping tool to visualise results

## A dynamic analysis in progress

As illustrated by Figure 4, the numerical platform MOSART "version 2" is composed by two main elements:

- The "Transport/Land use Model" component allows to model transport and land-use interactions and to measure accessibility. It integers geographical databases used by VISUM or GIS applications.
- The Webmapping application deals with cartographic results visualisation and dissemination.

MOSART "version 2" aims to provide a transportation/land use model to better understand transport behaviours resulting from public transport policies. Furthermore simulations of transport and land-use policies impacts on urban pattern will be considered. The MOSART project is divided as follow:

- in version 1, static modelling simulates isochrone accessibility impacts of an existing transport network or a new transport infrastructure considering a "ceteris paribus" hypothesis,
- in version 2 system modelling highlights relationship between transport demand and gravity-based accessibility considering a static land-use model,
- version 2 foreshadows therefore an interaction between transport and land-use system.

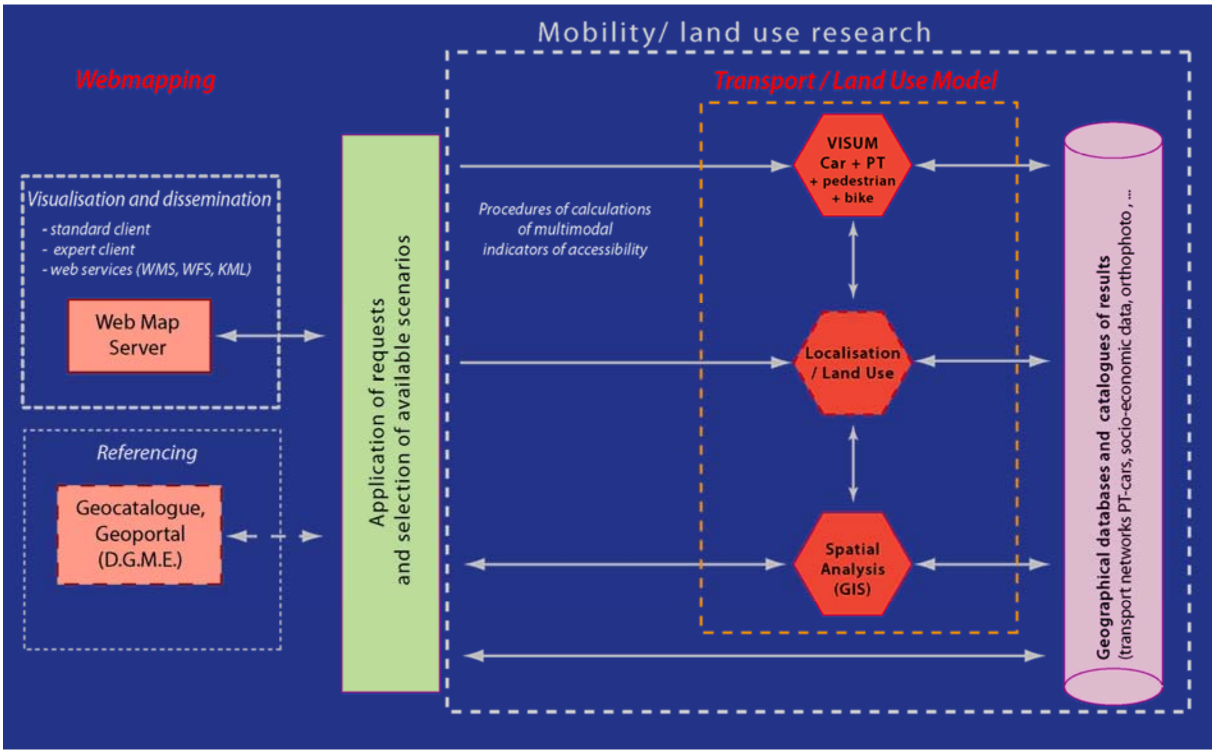


*Figure 4: Numerical platform of urban simulation architecture for MOSART "version 2"*

Up to date interactions between transport and land-use system are not yet modelled. A TRANUS-based model is planned to be implemented. Nevertheless a semi-dynamic analysis on transport modelling is operational. Such a transport model (4-stage model), entirely

executed in VISUM software, aims to integer road transport demand (and then road congestion level) on travel time and accessibility. The transport model implemented in MOSART as its impacts on travel time by car and access-levels is detailed in another paper presented in the WCTR 2010 (Mercier and Stoiber, 2010). The core of this urban model is that traffic predications and assignment varies according to different periods of the day. Two main periods are specified: a peak period presents traffic between 7 and 10 AM and an off-peak period corresponding to an average traffic level. While peak traffic is simulated according to traffic gathered between 7 to 10 AM by the French survey “Enquête Ménages Déplacements” in 2006, off-peak congestion is inferred using daily traffic.
Semi-dynamic transport system modelling is coupled to a static land-use model. Spatial distribution of population, opportunities and transport infrastructures are assumed to be constant. In spite of this restrictive hypothesis, applying transport land use model requires an extensive range of data related to spatial units, land use, spatial interactions and the transportation network (Rodrigue, 2006).

## A detailed spatial analysis

### *Spatial division*

The study area has been divided into squares 4,344 zones with their respective centroïds. Zone size varies according to location on the Lyon Metropolitan area owing to technical limits (number of zones should be inferior to 5,000 to use VISUM software) and easy reading. The Central Business District divided into 1,272 squares of 250 meters side. Suburbs are divided into 2,291 squares of 500 meters side and then suburban part is divided into 781 2 kilometers squares.
To prepare the “transport land-use interaction” stage, land-use database has been expanded with real estate data from PERVAL. This database provides much information on property deals (detailed location of flats or house, sale price, surface area, quality…) and allows to a very detailed spatial analysis.

### *Road, urban and interurban public transport network modelling*

The road network database has been prepared with SIS GIS and MySQL before being integrated to VISUM. A new detailed road section typology has been implemented to characterize each link according to approximately 50 road types.

*As shown by*

Figure 5 urban public transport has been manually recreated on VISUM and improved using digital maps (for tram and subway lines) and database from NAVTEQ (for bus lines). More than 2,300 stops have been generated including every public transport connections. A distinctive feature of MOSART “Version 2” is that the very detailed urban public transport network is coupled to precise timetables. For each line public transport timetables have been integrated according to frequencies and the different periods of the day: peak-hour periods from 6 to 9 AM and from 4 to 7 PM, off-peak hour periods from 9 to 12 AM and from 7 to 10 PM. A timetable based assignment is therefore implemented in VISUM.

Interurban public transport network, created in "Version 2", refers to regional rail network with 10 railway lines. Such as bus network, it was generated from NAVTEQ database. For each line, timetable has been integrated considering a typical weekday schedule. Note that railway stations located in Lyon are connected with the urban public transport network.

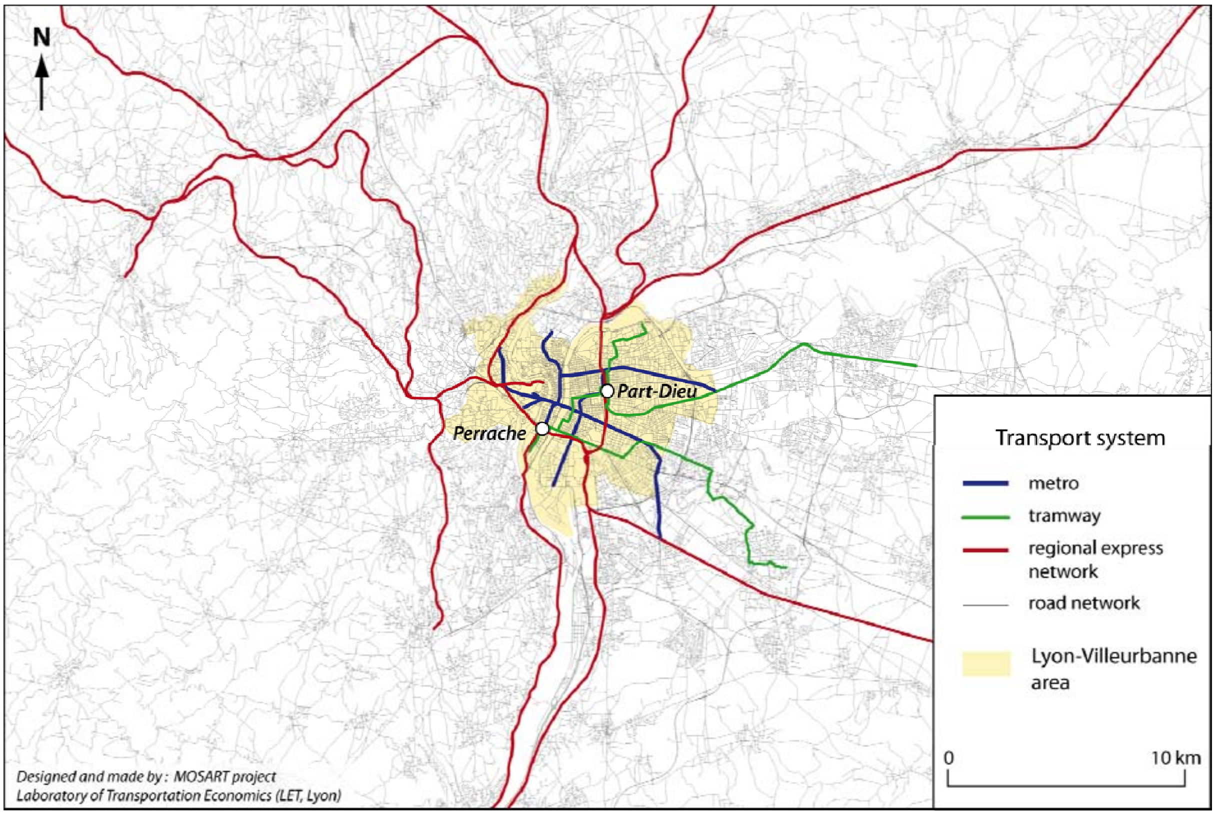


*Figure 5: Public transport networks*

Another improvement refers to connective lines. A connective line is used to enter road or public transport networks from the 4,344 zone centroïds. VISUM software connects centroïds to networks according to minimal Euclidean distance using a speed of 25 km/h to connect the road network and 3.5 km/h (corresponding to a walking speed to join bus, tram or sub station) to connect public transport network. The problem with Euclidean distance is that connections depend only on distance and never on network performances. For example, a centroïd located at 100 meters of a subway line and at 50 meters of a bus line is connected to the bus line even if the subway line is more efficient. An application has been developed in MOSART to implement a public transport modes hierarchy: subway-lines connections are preferred to tram-lines ones and high frequency bus-lines connections are favored to other lines. Note that this application on connective lines is coupled to another one to update spatial and attribute databases of public transport networks. This second application aims at automating route line and timetable changes in VISUM.

## Gravity-based access results

The second version of MOSART aims at improving access-measures not only using real and precise distance or time component (i-e travel costs) but jobs, shops, inhabitants… that could be reached (i-e travel opportunities). MOSART version 2 puts speed issues into perspective with land-use and density issues using gravity-based access measures. Through the performance of a transport network, accessibility becomes a measurement of the supply of opportunities available to a household, (Koenig, 1972).
Gravity-based index, introduced by Hansen in 1959, presents a measure of the intensity of the possibility of interaction. It estimates accessibility of opportunities from a zone i to all other zones j in which smaller and/or more distant opportunities provide diminishing influences (Geurs and Wee, 2004). Access-results are proportional to the number of goods in the destination zone j weighted by an impedance function of generalized cost. Hansen revealed that "for user satisfaction to remain constant (irrespective of change), any linear progression in the cost of travel should be associated with a progression multiplying the choices offered at the destination". Accessibility measure was chosen from many measures discussed in the literature mainly because of its consistency with the surplus theory, cost benefit analysis (Raux and *al.*, 2008) and Weibull's axiomatic system.

Gravity-based accessibility can be described as:

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

Where :
$E_j$ denotes the mass of opportunities at location j ( the number of jobs)
$C_{ij}$ denotes the travel cost (or generalised cost) between i and j. $C_{ij} = P_{ij} + vT_{ij}$ where $P_{ij}$ are monetary costs, v the value of time and $T_{ij}$ travel time.
$\beta$ denotes a cost sensitivity parameter
n denotes the number of locations

Job-access results presented in this paper only aim at illustrating the different types of outputs produced by MOSART. These results won't be analyzed in public policies point of view. MOSART transport policy oriented results are discussed in a joined paper submitted for the WCTR 2010 (Crozet and *al.*, 2010). In a first time the paper proposes a peak/ off-peak comparison of job-access by car in the Grand Lyon perimeter.

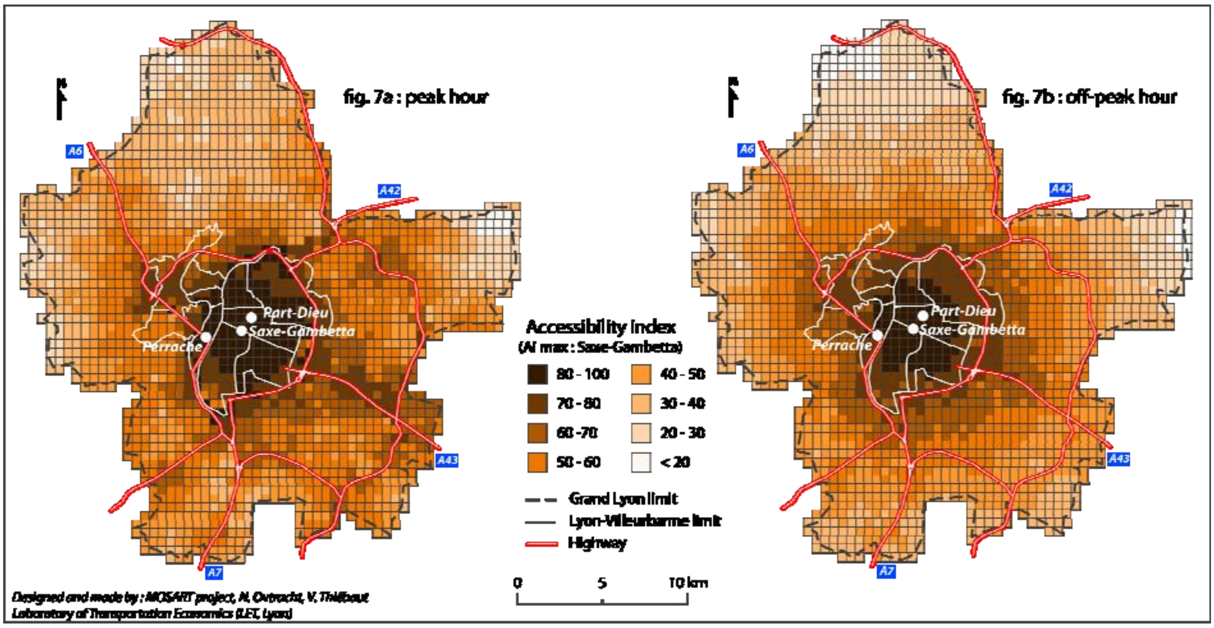


*Figure 6: Job-access by car – comparison of peak and off-peak periods*

Figure 6 represents job gravity-access indicators for each part of the study area, divided in squares of 500 meters side. The darker the colour, the higher the accessibility indicator is. During off-peak hours, job accessibility by individual car is the highest in the city centre. The high density of jobs located in the central part of the urban area explains this result, which is not specific to Lyon. Results are different at peak hours. The lower average speed on the highway network and the creation of several congestion points are significantly modifying job-access representation. The central part of Lyon keeps a high accessibility but some surrounding areas end up being somehow farther away (in the North). It is interesting to note that zones located on the east of the urban area, close to urban motorways are faced with a high relative gain. In spite of congestion on peak hour, motorway speeds are less decreasing than in other roads.

In a second time, Figure 7 shows the gravity accessibility differential between public transport and private car at peak hours. The pink and red squares represent the areas where accessibility by public transport is better than accessibility by private car. Blue squares reflect the opposite situation.

This figure stresses again the positive impacts of urban motorways on car access-level. Close to rapid highways (in red) the blue colour is dominant. However, alongside public transport axes (subway and tramway in yellow), pink and red are prevailing. At the Grand Lyon scale, public transports can be more efficient than car on work trips. While car travel time is very sensitive to the congestion level, public transport with exclusive lanes is not affected by the car traffic level.

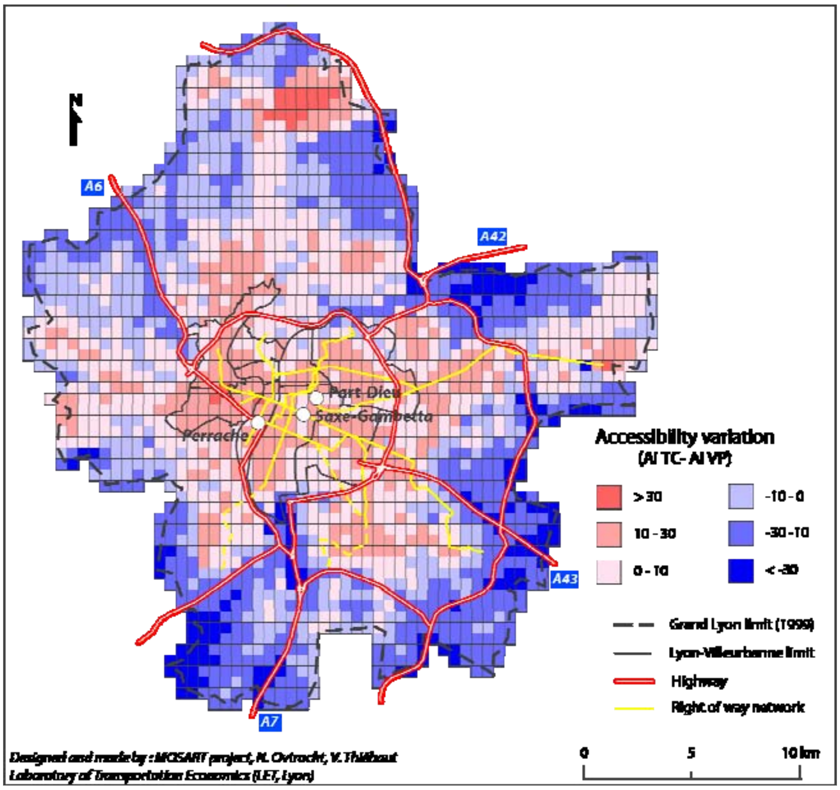


*Figure 7: Accessibility differential between public transport and car on peak hour*

Figure 8 presents job-access level by public transport at a scale higher than the Grand Lyon perimeter. It illustrates impacts of regional rail network on job-access for public transport users located outside the Grand Lyon perimeter. Compared to the previous figures, an area in the South-East has been added, served by suburb trains. The quality of the railway service, less than 30 minutes to reach Lyon's centre from la Verpillière, with a high frequency, allows for this area far away from the city centre, the same accessibility as for closer suburbs. Quite expectedly, suburb trains are packed, as well as parking located around train stations.

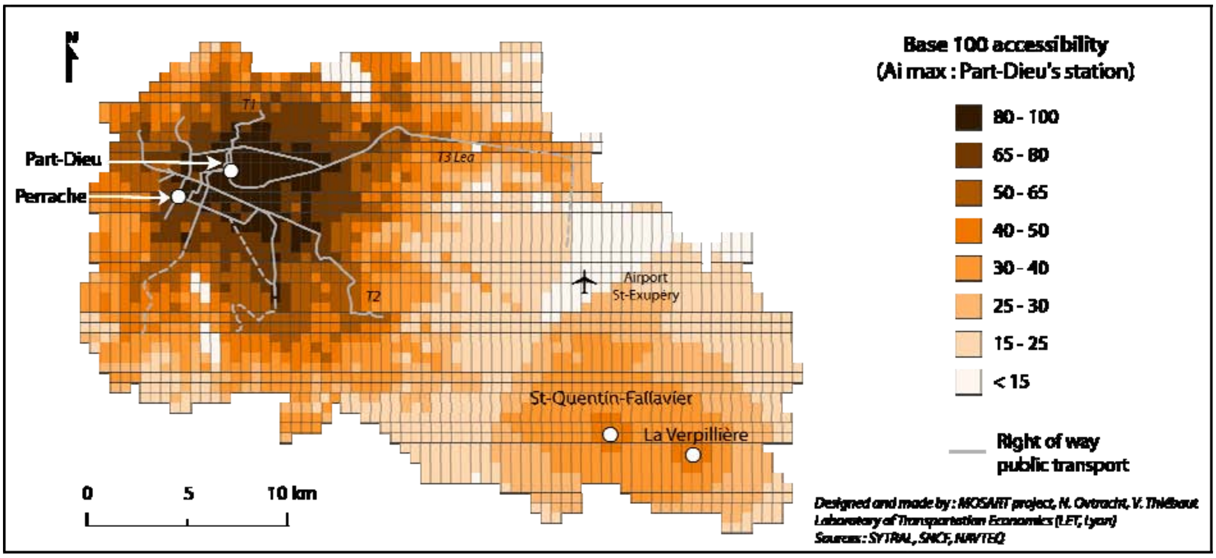


*Figure 8: Job accessibility by public transport on peak hour*

# CONCLUSION

An increasing urban travel demand coupled to congestion and environmental constraints encourages policy makers to find new transport and urban solutions maximizing accessibility and minimizing environmental impacts. At the same time, individual have to think about their location choice in an accessibility and environmental point of view. In this context, the MOSART project has been implemented since 2005 by the "Laboratoire d'Economie des Transports" of Lyon to model and simulate transports policies using access-based indicators.
The MOSART tool was implemented in a first time as GIS in transportation: two transports networks (road and urban public transport networks) and basic land-use data are incorporated to allow static access analysis. "Time-based" access results illustrate the urban area reached under a time constraint. MOSART has moved, in version 2, to an innovative modelling platform for planning sustainable mobility. Integration of a four-step urban transportation model system associated to updated land-use data at a very detailed zonal division make easier dynamic analysis to forecast different transport/land-use policy scenarios. An innovative aspect of MOSART refers to an analysis on both urban speed issues and land-use patterns. Combining these two interrelated aspects on an access-based point of view, MOSART presents a new approach of transport and land-use polices assessment. Cartographic results are essential to communicate to policy makers.
Two types of developments of MOSART are expected. First, an interactive web-mapping tool: modeling results will be visualized using a web user interface (http://mosart.let.fr) available first for the project partners and then for the general public. Then, a transport-land use model will be implemented to understand how transport structure (by accessibility) can affect spatial development.

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