Evaluation of car traffic reduction potential in urban area, Paris and Lyon case-studies

Marie-Hélène Massot, Jimmy Armoogum, Patrick Bonnel, David Caubel, Laurent Hivert, Dominique Mignot

Evaluation of car traffic reduction potential in urban area

Paris and Lyon case-studies

European Transport Conference
9-11 September 2002
Homerton College, Cambridge, UK

Authors:

MASSOT Marie-Hélène , INRETS, Research Director, (massot@inrets.fr),
ARMOOGUM Jimmy, INRETS (armoogum@inrets.fr),
BONNEL Patrick, LET-ENTPE (patrick.bonnel@entpe.fr),
CAUBEL David, LET-ENTPE (david.caubel@entpe.fr),
HIVERT Laurent, INRETS (hivert@inrets.fr),
MIGNOT Dominique, LET-ENTPE (dominique.mignot@entpe.fr).

Abstract:

The private car currently dominates travel in large metropolitan areas and its use is on the increase, in spite of the fact that public opinion is generally in favour of the development of public transport and political statements which reflect this opinion. Furthermore, the available projections and an analysis of the potential effect of conventional policies (restricting parking, improving public transport, economic instruments (urban toll) or tax measures (Internal Tax on Oil Products – TIPP)) indicate that although such policies are able to exert some control, it is limited.

The question that this research directed by INRETS will attempt to answer is therefore: could a major metropolitan area operate with a radically different transport system that is based principally on the use of modes other than the automobile? By "radically different", we mean a system in which use of the conventional automobile would be reduced in a non-marginal manner, by, say, between a third and a half of all private car vehicle-kilometres.

This research does not attempt to justify a move towards a radically different system, as much has already been said on this topic. Instead, the project will perform different transport simulations and apply rules in order to assess the effect on the use of modes in the densely populated zone of the Greater Paris Area and the Greater Lyon Area.

Transport scenarios have been designed to incorporate a progressive improvement in public transport supply in the following respects: increase in speeds on the roads, increase in service frequencies during off-peak periods, creation of exclusive public transport lanes, reserving radial roads for public transport, extension of metro and regional express rail (RER) lines and reorganisation of bus routes in response to this. We have also devised and simulated a set of appropriate accompanying strategies that are intended to improve the effectiveness of public transport supply, for example policies to encourage the use of the bicycle or the car as a feeder mode for public transport (park and ride schemes) and passenger information strategies.

The methodology, developed by INRETS since 1996 has been applied on Paris and Lyon region based on the last household travel survey conducted in each area. For each transport scenario, Paris and Lyon models are used to calculate public transport time for all trips whatever is the actual mode of transport. We then applied the procedure of mode transfer to assess the effect of each of these scenarios on mode use. The procedure is based on automatic rules. Trips, or more precisely round trips, are assigned to one or other of the alternative modes on the basis of elimination rules (no walking for distances over 2 kilometres, no cycling over 8 kilometres, no modal transfer if the purpose of the round trip is for escorting purposes etc.) and on the basis of constraints (individual travel-time-budgets, the length of each trip and round trips, the existence of transport supply, etc.). This system of rules and constraints constitutes the core of the modal transfer procedure, which examines the possibilities of substitution in the context of the different transport scenarios.

The paper presents both the methodology and results obtain from Paris and Lyon case studies.

1. The issues

The private car currently dominates travel in large metropolitan areas and its use is on the increase, in spite of the fact that public opinion is generally in favour of the development of public transport and political statements which reflect this opinion. Furthermore, the available projections and an analysis of the potential effect of conventional policies (restricting parking, improving public transport, economic instruments (urban tolls) or tax measures (Internal Tax on Oil Products – TIPP)) indicate that although such policies are able to exert some control, it is limited.

The question that this research will attempt to answer is therefore:

Could a major metropolitan area operate in an acceptable manner with a radically different transport system that is based principally on the use of modes other than the automobile?

In this context, by "acceptable", we mean a system which would provide all users with speeds and daily transport time-budgets which are comparable with those of the present-day system, at a social cost that is equivalent or lower and, of course, with a significant improvement in the urban environment.

By "radically different", we mean a system in which use of the conventional automobile would be reduced in a non-marginal manner, by, say, between a third and a half of all private car vehicle-kilometres.

The "Pari 21" research project does not attempt to justify a move towards a radically different system – a lot about the benefits and disadvantages of cars in cities has already been said (Massot, 1999). Instead, the project will perform simulations and assess, from the point of view of individuals and of society, the feasibility of a transport system that is based mainly on the use of modes other than the private car in the densely populated zone of the Greater Paris Area (Paris city plus the inner suburbs, Cf. map1) and of the Greater Lyon Area (Lyon city plus the inner suburbs, which corresponds to the administrative Greater Lyon zone, Cf. map 1).

By constructing and evaluating transport policy scenarios, this research also aims to measure the potential for reducing car use in highly urbanised zones, particularly that which results from the reduction in journey speeds which are a likely consequence of the policies in question.

2. Methodology

The approach allows us to simulate and measure *the potential market for transport modes other than the private car*.

The method is based on repeated iterations of a simulation model which combines the assignment of trips to modes other than the automobile according to several improving public transport scenarios. Demand is channelled towards personal modes (walking, cycling), public transport routes and a combination of personal and public modes.

These iterations are based on:

- household travel survey of both conurbation (the 1991-1992 Paris Region comprehensive travel survey, and the 1994-1995 Lyon Region household travel survey, Cf. map 1) which record all trips made in a typical day by all the individuals of surveyed households living in the zone;
- public transport assignment model which assigns trips on public transport network on the base of the shortest path for each car trip (we use IMPACT model developed by the RATP (main Paris Public Transport Operator) in case of Paris Region and TERESE model developed by SEMALY consulting group based in Lyon);
- the speed of walk and bicycle which provide potential alternative to private car round trips.

Trips, or more precisely round trips (i.e. the sequence of all trips made between each time the individual leaves home and returns home), are assigned to one or other of the alternative modes on the basis of elimination rules (no walking for distances over 2 kilometres, no cycling over 8 kilometres, no modal transfer if the purpose of the round trip is for escorting purposes, etc.) and on the basis of constraints (individual travel-time-budgets, the length of each trip, the existence of transport supply, etc.). This system of rules and constraints constitutes the core of the modal transfer procedure, which examines the possibilities of substitution in the context of present-day or future transport supply and allows us to identify realistic margins for manoeuvre with regard to personal travel.

The modal transfer procedure applies to several supply scenarios which provide a picture of what is possible in the area of modal split. These scenarios have been designed to incorporate a progressive improvement in public transport supply. The new services in the scenarios have been based on the infrastructure and services described in the Urban Travel Plan for the Greater Paris Area, on the Master Plan and on the 12th and 13th State-Region plan contract (2000-2010). In case of Lyon Conurbation, the scenarios have been based on the Urban Travel Plan for the Greater Lyon (2000-2010) + a development of RER scheme.

In Case of Paris Region, we have also devised and simulated a set of appropriate accompanying strategies that are intended to improve the effectiveness of public transport supply, for example policies to encourage the use of the bicycle or the car as a feeder mode for public transport (park and ride schemes) and passenger information strategies.

Each simulation provides a potential transfer of private car vehicle kilometres to each of the other modes. Even if we simulate different public transport scenario for the future, the transfer is evaluate for the rounds trips of both Paris and Lyon surveys. Therefore, there is no modification of the activity pattern of the surveyed persons nor induced trips due to improved transport supplies performance.

In this section we develop first the basic principles of the transfer procedure (section 2.1). We follow with the description of the transfer procedure (section 2.2). Then we describe the public transport scenario (section 2.3) and the data used (section 2.4). And finally we discuss the methodology (section 2.5).

2.1. Principles of the transfer procedure

This section sets out the main principles and rules used by the algorithm that deals with the transfer of “private car” round trips to walking, the bicycle or public transport that have been developed in the framework of this research project. The five main principles of the algorithm were laid down as early as 1996 at INRETS (Gallez, Polacchini, 1996) and taken up in a research project that examined the potential for modal transfer in the Greater Paris Area (Massot, 1999). This paper applies the same principles and describes the system of rules and constraints that has been developed with reference to the travel characteristics of the inhabitants of the densely populated zones in the Paris and the Lyon regions.

We shall start by describing the four basic principles of the approach and then give an account of the major rules associated with each.

2.1.1. Round trips

The modal transfer procedure is based on transfer rules that apply to round trips or trips away from home. A round trip is defined as the sequence of trips made between leaving home and returning home. An individual can make several round trips in the same day.

This principle is a departure from modal transfer evaluations that consider individual trips (Mackett, Robertson, 2000). It is based on the firmly-based hypothesis (Jones, 1990; Boulahbal, 1995) that an individual’s modal choice depends on the activities which he/she wishes to conduct when outside the home or during the day. Conversely, we also show that an individual’s range of modal choices depends on his/her desired activity schedule. The procedure which is described in this project takes into account the close link between an individual’s ability to use a given transport mode and the organisation and geography of the trips he/she makes when outside the home.

Four rules have been developed on the basis of this principle:

Rule 1 any round trip whose first trip is by car is subjected to the transfer procedure. In the vast majority of cases, when the car is chosen for the first trip in a round trip it is also used for the others (in our sample, 93% of the trips in the Greater Paris Region which were part of round trips whose first trip was by private car were by car. The percentage was 95% for the Greater Lyon Region);

Rule 2 if at least one of the trips in a round trip is judged not to be transferable, the same is considered to apply to all the trips in the round trip;

Rule 3 all the trips in a round trip are transferred to a single mode;

Rule 4 only round trips that take place entirely within the survey perimeter and which are at least partly located within the densely populated zone (see Map 1) are considered. The purpose of this rule is to try to include all the car round trips which generate car traffic within the densely populated zone of the conurbation.

2.1.2. Compliance with individuals' activity schedules

The second principle is based on compliance with individuals' activity schedules. In the same way that we do not take account of trip generation or changes in trip characteristics (other than the mode) which would result from an alteration in transport supply in the different scenarios, we do not wish to modify the characteristics of the activities performed by the individuals. Consequently, all round trips which include activities for which the car seems to be the most suitable or the essential mode have been excluded from the procedure. On the basis of an analysis of the travel practices of the studied population we have placed two trip purposes in this category. Lastly, round trips which include trips made at night have been excluded from the procedure, both for reasons of security and because of the lack of public transport:

Rule 5 round trips which include one or more trips for the purpose "exceptional and weekly purchases" have been excluded from the procedure. The purchases in question are often bulky and heavy and frequently require a car;

Rule 6 the car has also been considered as essential for any round trip which includes more than one escorting trip. If there is only one escorting trip in the round trip it is subjected to the transfer procedure when the escorted person is not too young or too old. If the round trip turns out to be transferable, the trip made by the escorted person(s) is transferred to the same mode as the driver, without considering any change in the travel conditions for the escorted persons on the grounds that in the majority of cases the survey does not provide information about the general travel practices of the escorted persons;

Rule 7 round trips which include trips made at night (midnight to 5 a.m.) are not transferable.

2.1.3. Compliance with daily travel time-budgets

The third principle lays down that the first condition for transport is the more or less complete compliance with the individual's daily travel time-budget. This principle allows us to monitor any increase in travel time that results from a transfer from the car to a slower mode and to maintain consistency for each individual between the time required for activities and the time required for travel (Wiel, 1999, Schäfer, 2000). The potential increase in the daily travel time-budget is therefore controlled, by applying a travel time-budget increase margin for the individuals affected by the procedure. The maximum value of this margin is fixed a priori, and depends on the individual's initial travel time-budget and the average travel time-budget of the group to which he/she belongs (12 groups have been defined on the basis of combinations of occupation, gender and activity). The constraints and rules that apply to the travel time-budget have been specified on the basis of a detailed analysis of the travel of residents in the Greater Paris and Greater Lyon Areas (Massot et alii, 2000; Bonnel, 2000):

Rule 8 any individual whose initial travel time-budget is strictly higher than 300 minutes will be excluded from the transfer procedure as will, obviously, all of this individual's trips. This constraint is based on the hypothesis that above a certain daily duration, transport mode changes are unlikely, or even impossible, while still satisfying the constraints;

Rule 9 when an individual's initial travel time-budget is twice as high as the average travel time-budget of the group to which he/she belongs, transfer is only possible if the travel time-budget remains the same or diminishes. In this case, it is considered that the travel time-budget has reached its maximum value and therefore that the individual's travel time-budget cannot increase;

Rule 10 the margin by which an individual's travel time-budget can increase cannot be greater than 25% of the typical travel time-budget of the individual's category in the case of the Greater Paris Area (for Lyon, as the daily travel time-budgets are smaller, we have applied a maximum margin of 30% which is very close to that observed in the Paris conurbation);

Rule 11 in no case can a transfer lead to an individual's travel time-budget increasing by more than 30 minutes.

2.1.4. Modal segmentation of the round trip market

The procedure employed here is based on a fourth principle of segmentation of the travel market into submarkets – markets for walking, the bicycle and public transport – which provides the means of considering potential competition between them in terms of distance and speed. Transfer of a round car trip to one of the three alternative modes depends on the total distance of all the trips in the round trip. Several distance classes have been specified based on an analysis of all the round trips whose principal mode is walking or the bicycle (Massot et alii, 2000; Bonnel, 2000).

Rule 12 Transfer to walking

On the basis of the distances and durations stated by respondents during the travel survey, we have selected the values of the upper bound of the third distance quartile to establish the distance threshold and the travel speed for walking. We have adopted the following rule as a result of the homogeneity that applies to the distances and speeds observed in the Greater Paris Area sample, irrespective of the dimension that is considered (age of the person, trip purpose, etc.): any round trip with a total length which is equal to or less than 2 kilometres can be transferred to walking and we assume that a round trip that is transferred to walking is made at a speed of 3.5 km/h.

In the case of Lyon, there is more dispersion in distance and speed depending on the age of the individual, in particular in the case of persons of 61 years of age and over. As a result of this dispersion we have selected the value of the third quartile for each age group as the distance threshold (this varies between 1.96 and 2.31 km) and the average speed of the group (which varies between 3.24 and 4.5 km/h).

Rule 13 Transfer to the bicycle

Bicycle trips are not as homogeneous as walking trips. In spite of the small samples, our analysis of the surveys gave different segmentations in the two locations. For Greater Paris we have considered three distance classes for bicycle round trips. For Lyon, age was again the most indicative variable. As with walking, the distance classes we have chosen correspond to the upper bound of the third quartile of the distribution (Table 1).

Rule 14 Transfer to public transport

Transfer to public transport (bus, metro, Regional Express Rail (RER), SNCF train) is obviously limited by supply. The public transport travel time for all trips which take place within car round trips has been calculated using a traffic assignment model. The calculation in question has been performed for the reference network and then for the different networks that correspond to each of the public transport improvement scenarios. These are therefore theoretical travel times, unlike the stated travel times obtained from the surveys.

For the Paris conurbation, these trip times have been calculated using the assignment module in the RATP's IMPACT model. This module performs shortest time path assignment. The model includes an extremely detailed description of public transport supply and identifies the location of all public transport stops. Furthermore, the Comprehensive Transport Survey used a grid consisting of 300 metre squares for precise identification of trips, origins and destinations. It is therefore possible to measure access times to public transport fairly accurately. This will be used in the context of some public transport supply scenarios for which the use of two-wheelers or a car for feeder trips will be tested for access distances above certain thresholds. Public transport supply has been specified for both off-peak and peak periods so that it is possible to calculate trip times for both (Massot et alii, 2000).

For the Lyon conurbation, the trip times are calculated using the assignment module in the TERESE model that has been developed by the SEMALY. This module also conducts shortest time path assignment. The description of supply is not as detailed as in the case of the Paris conurbation. It is based on a division of the Lyon conurbation into 196 zones which does not allow access times to be precisely identified. The calculated times were then transferred to the household travel survey base which provides a division into 357 zones. This transfer was made possible by the creation of a transition matrix between the two zonings (Bonnel, 2000). The SEMALY database includes only evening peak hour supply. Consequently, the transfers have been estimated on the basis of the evening peak hour public transport trip times.

Table 1: Distance class for transfer of round trips to the bicycle and the speed of transferred round trips

Paris conurbation				
Purpose	Work	Shopping	Other	
Maximum distance threshold for the rounds trips	11 km	8 km	3 km	
Speed of transferred round trips	11 km/h	5 km/h	8 km/h	
Lyon conurbation				
Age group	5 to 17 years	18 to 29 years	30 to 60 years	61 years and over
Maximum distance threshold for the rounds trips	2.78	6.38	6.36	2.93
Speed of transferred round trips	9.21	10.11	8.11	5.24

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92; LET based on the Household Travel Survey 1994-1995.

2.2. The procedure

On the basis of the above set of rules, the transfer procedure is applied sequentially to all the car round trips performed by each individual (Figure 1). As priority has been given to individual travel time-budget constraints, the transfer of an individual’s round trip or round trips is only considered if these are respected:

- if the travel time-budget constraints or if the purpose and time of day constraints for the round trip are not satisfied:

⇒ the individual’s car round trip is not transferred;

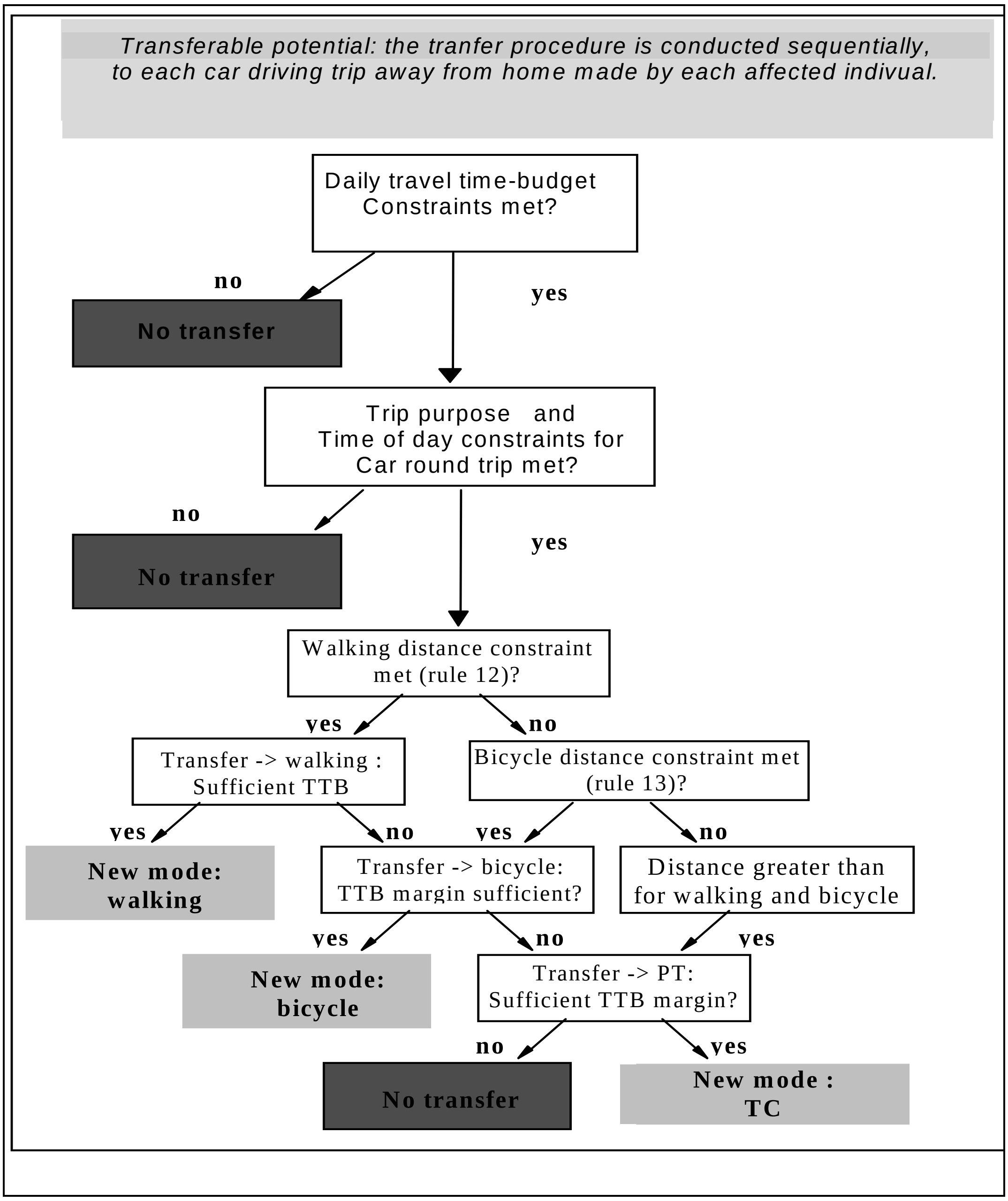
- otherwise, the car round trip is transferred according to the following procedure: the first transfer mode that is tested (walking, bicycle or public transport) depends on the total distance covered in the round trip:
- if the increase in the travel time-budget after transfer is below the threshold that has been set on an a priori basis:

⇒ the procedure is successful, the transfer is possible and the travel time-budget is changed accordingly;

- if the increase in the travel time-budget exceeds the threshold, transfer to a faster mode is tested (the bicycle in the case where transfer to walking was tested first, public transport if transfer to the bicycle was tested first);
- if no mode is able to limit the travel time-budget:

⇒ the transfer fails for all the trips in the round trip.

Figure 1: Simplified modal transfer procedure of individual round trips



Source: INRETS

2.3. Construction of the public transport scenarios

The transfer procedure was first applied to public transport supply as it stood at the dates when the surveys of the Paris and Lyon conurbations were each conducted. On the basis of an examination of the features of the transferred round trips and the non-transferred round trips, we have proposed several public transport supply improvement scenarios. The procedure used to construct these scenarios involved successive improvements to supply, including the following:

- increase in the off-peak hour frequencies to bring them up to the level of the peak hour (only for the Paris conurbation);
- increase in bus speeds by increasing the number of exclusive bus lanes. Applying this measure to all the road networks of both conurbations leads to the application of the maximum speed that is possible in view of the speeds that are permitted in the Highway Code, the access time to bus stops and road configurations. This maximum speed has been estimated by the bus network operators at 15 km/h in the most central zone, 20 km/h in the suburbs and 25 km/h in the outer suburbs (see Map 1, description of zones);
- extension of the high capacity public transport networks (tram, metro, regional express rail) in accordance with the development plans of the two conurbations:
  - the Urban Travel Plan for the Greater Paris Area, and the Master Plan based on the 12th and 13th State-Region plan contract (2000-2010, RATP, 2000);
  - the Urban Travel Plan for the Greater Lyon (2000-2010), in case of the Lyon conurbation (SYTRAL, 1997);
- development of regional rail transport supply in the case of Lyon;
- general introduction of park and ride schemes near all radial public transport routes in the Paris conurbation and a strategy to provide public transport timetable information enabling users to reduce their waiting times at bus stops.

As the levels of public transport supply are very different in the reference situation in the two conurbations (Table 2), different scenarios had to be provided for each context. The more detailed nature of the data on the Paris region enabled us to construct 7 supply scenarios (Massot et al., 2000). Only 5 scenarios were specified for Lyon (Bonnel et al., 2002). In this paper, we shall discuss only the most contrasting scenarios:

- For the Paris conurbation:
  - HP-HC 90 which corresponds to the network as it stood in 1990 shortly before the Comprehensive Transport Survey was conducted in the Paris region. This is therefore the reference network;
  - HP99 + Mobilien which corresponds to the network as it stood in 1999, with an extension of peak hour frequencies to off-peak periods and the implementation of the Mobilien plan (creation of 60 exclusive bus lane routes in Paris and in the suburbs, RATP 2000);
  - HP2010 Mobilien + 15,20,25 which is the same as the previous network but with an increase in supply in the outer suburbs with the creation of intersuburban routes and an increase in rail supply on the basis of the Masterplan that is based on the 12th and 13th State-Region plan contract. It is also accompanied by a restructuring of the bus network to match rail supply. Finally, this network includes the creation of exclusive bus lanes everywhere leading to speeds of 15 km/h in the centre, 20 km/h in the inner suburbs and 25 km/h in the outer suburbs becoming generalised;
  - HP2010 Mobilien + 15,20,25 + accompanying strategies which corresponds to the above network with a general provision of park and ride facilities adjacent to all radial public transport routes in the Paris conurbation with the possibility of using the bicycle or the car for feeder trips to public transport, and a strategy to provide public transport timetable information enabling users to reduce their waiting times at bus stops;
- for the Lyon conurbation:
  - HP95 which corresponds to the network as it stood in 1995, the date at which the Household Travel Survey for the Lyon conurbation was conducted. This is therefore the reference network. However, as the network has only been coded during the peak period, this scenario

implicitly features an application of peak hour frequencies to off-peak periods. It therefore already represents a considerable improvement on the real situation in 1995;
- HP2010 PDU which corresponds to the scenario described in the Plan de Déplacements Urbains (Urban Travel Plan) for the conurbation in the year 2010 (SYTRAL, 1997). In particular, this plan envisaged the creation of 10 high capacity routes in addition to the 4 existing metro lines;
- HP2010+ rail +15,20,25. This is the previous scenario with a general development of rail services (using the existing network which is little used at the present time). As in the case of the Paris conurbation, we have also included the creation of exclusive bus lanes which leads to a speed of 15 km/h in the centre, 20 km/h in the inner suburbs and 25 km/h in the outer suburbs.

Table 2 shows the scale of the increase in the public transport supply: in comparison with the reference scenarios, simulations with the most ambitious scenarios result in an increase of 44% in seat kilometres for Paris and of 92% for Lyon. The second figure represents a doubling of supply and is more than two times the increase in capacity obtained for the Paris conurbation. So the simulated changes in the public transport supply are not marginal, even if in the most ambitious network in Lyon, supply in terms of seat kilometres per resident is at the same level as it was in Paris in 1990.

Table 2: Supply indicators for the public transport scenarios

	Greater Paris area			**Greater Lyon area**		
	HP-HC 90	HP99 + Mobilien	HP2010 Mobilien + 15,20,25	HP95	HP2010 PDU	HP2010+ rail + 15,20,25
Seat kilometres per year (billion)	106.7	143.4	154.2	7.2	12.6	13.9
Population of survey zone (thousand)	10 464 (Paris region, 1990)			1 195 (in 1995)		
Seat kilometres per person per year	10 023	13 704	14 736	6 085	10 554	11 653

Sources: INRETS, based on IMPACT models (RATP)
LET, based on TERESE models (SEMALY)

2.4. Description of the data

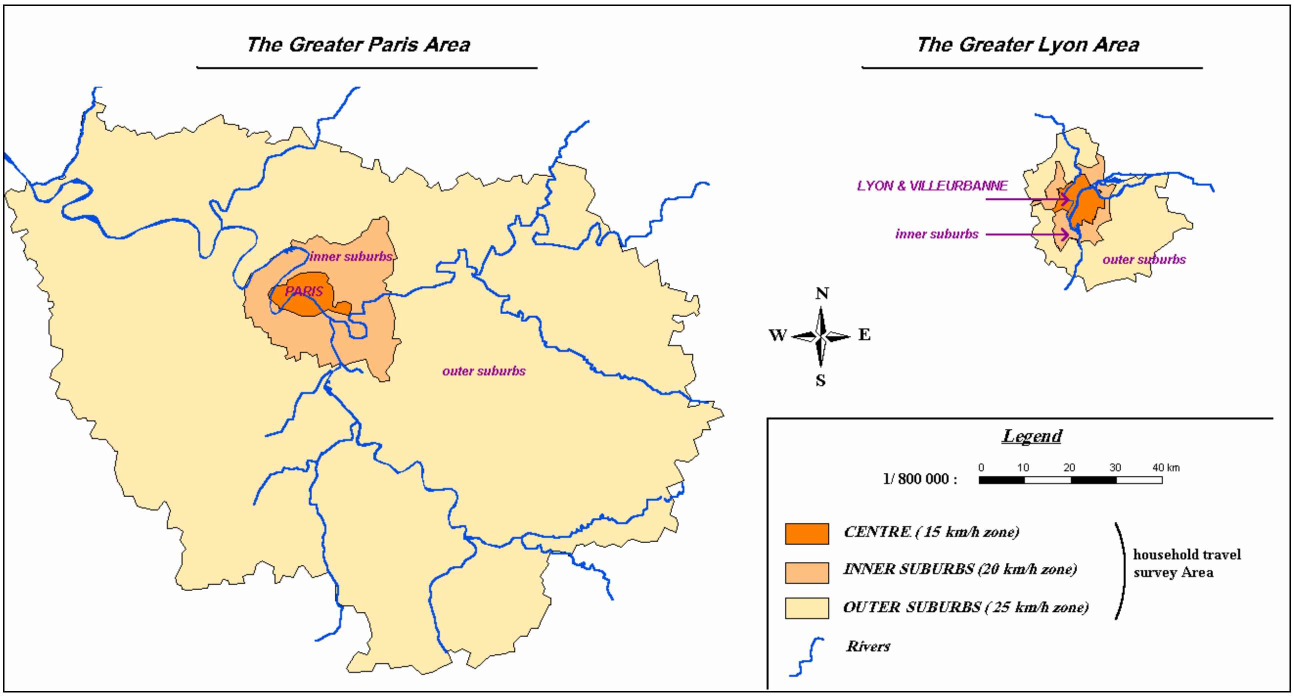
The transfer procedure has been applied to the two most recent household travel surveys in the two studied conurbations. These are the 1991-1992 Comprehensive Transport Survey which was organised by the DREIF for the Paris conurbation (DREIF, 1995) and the 1994-1995 Household Travel Survey that was organised by SYTRAL for the Lyon conurbation (CETE de Lyon et al., 1995). The two surveys use a similar methodology (CERTU, 1998). In both cases, face-to-face interviews were conducted to collect details about the previous day’s travel from all persons over 5 years of age in the target households, as well as the socio-economic characteristics of the household and the individuals in it. The size of the samples in the survey is shown in Table 3 and the survey perimeter on Map 1.

Table 3: Surveys description

	Number of surveyed households	Number of respondents	Number of trips described by respondents	Number of round trips described by respondents
Paris conurbation				
Surveyed sample	11,291	26,009	91,243	35,435
Weighted sample	4 293 508	9 643 887	33 653 597	12 983 000
Lyon conurbation				
Surveyed sample	6 001	13 997	53 213	20 781
Weighted sample	536 317	1 195 189	4 659 777	1 802 120

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

Map 1: Study zones



2.5. *Discussion of the methodology*

The original and innovatory features of the method depend on the modal transfer procedure that has been developed.

Firstly, the modal transfer procedure considers all trips on each occasion the individual leaves home (round trips) and therefore breaks with simplistic transfer procedures that consider each trip separately. Secondly the procedure is "sequential": it is applied successively to each of the times the individual goes out in his or her car in the course of the day. The third important dimension, lays down as a first condition for modal transfer a strict or partial respect of the individual's daily travel-time-budget. The constraint imposed by the individual's daily travel time acts as a generalised daily travel speed indicator which can play a role in the procedure in order to make transfer more or less likely: whether individuals will accept an increase in travel time-budget or not, and if they will how much of an increase, is an integral part of the simulation program. This rule places travel time at the centre of the methodology, thereby making speed a key part of the system, and means that it is possible to measure how it contributes to the effectiveness of scenarios and how it affects individuals in the context of strategies aimed at reducing passenger car use in the zone.

We shall end this discussion of the methodology by stating a number of hypotheses. Apart from supply scenarios in the general sense of the term and how these affect the daily travel of individuals affected by the transfer, we shall adopt an “all other things being equal approach”. Thus, we shall consider that the following are invariant: the population and activities in the study zone, both with regard to the numbers of jobs and their location; the major components of individual activity schedules; the major aspects of transport technology (means of powering engines, the type of vehicles); the unit costs of using both personal and public modes. The effects that result from any change in supply, in particularly trips that are generated by increased speeds or improved reliability on transport networks, have not been considered either.

Some will see these hypotheses as somewhat limiting in the context of a forecasting process. However, we take the view that if all these criticisms, admittedly justifiable, were taken into account the study would move into different territory from that chosen at the outset, namely forecasting on the basis of present-day conditions in order to initiate debate by giving an idea of the scale of the stakes and the potential for reducing the role of the automobile on the basis of observed behaviours and policy options which are frequently suggested but not evaluated with reference to the stated objectives and by applying a correctly implemented, coherent methodology that can be understood by as many people as possible.

3. Principal results

The first stage consists of identifying the potential number of transferable round trips, i.e. establishing which round trips comply with rules 1 to 4 (section 3.1). We next quantify the potential transfer of car round trips towards more environmentally friendly modes with reference to the current situation – i.e. the transport supply and the travel time-budget at the survey date (section 3.2). This potential corresponds to the proportion of car users who choose to use the car even though it is not the fastest mode. In the next stage (section 3.3), we permit an increase in the travel time-budget according to the rules set out in section 2.1.3 (rules 9 to 11). This allows us to quantify the increase in potential transfer when the travel time constraint is relaxed. The next stage is to gradually introduce the different public transport improvement scenarios (section 3.4). This means that we are able to quantify the effect of an improvement in the performance of the public transport system. The last stage involves taking our approach as far as possible by questioning rules 5 and 6 that relate to shopping and escorting activities (section 3.5). This last stage in a way identifies the maximum transfer potential that could be achieved without fundamentally questioning the operation of the city, residential locations and the location of activities. The foregoing sequence of stages illuminates the debate about the control of space and the car in cities (section 3.6).

3.1. Identification of transferable potential

In the Paris conurbation, only one round trip in six is potentially transferable (with reference to rules 1 to 4). However, the proportion is twice as high in the Lyon conurbation because (in driver-kilometre terms) the car has a much larger share of the market (Table 4). These round trips include, on average, a little under three trips. Again a little more than one person in six has made round trips included in the transferable potential in the Paris region, while the proportion is twice as high in the Lyon conurbation. Lastly, the average distance covered in the round trips is more than 30 km in the

Paris conurbation and a little over 10 km in the Lyon conurbation. The size of the conurbation seems to play a particularly important role. The analysis of the results in the following sections will show that the greater distance has an effect on the volumes of transfers and the modes involved.

Table 4: Transferable potential

Number of round trips	Number of car round trips subjected to the transfer procedure (complying with rules 1 to 4)	Number of trips contained in the round trips subjected to the transfer procedure	Number of persons making round trips subjected to transfer procedure	Number of driver vehicle-kilometres in round trips subjected to the transfer procedure.
Paris conurbation				
12 983 000	2 173 000	6 402 000	1 701 000	65 896 000 km
Lyon conurbation				
1 802 120	672 896	1 866 476	436 000	7 160 000 km

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

3.2. Transfer potential in the current situation

The margins of manoeuvre available to individuals are far from non-existent. From the first iteration, i.e. on the basis of 1991 car usage data and constant public transport supply (those for 1990) it is apparent that 8% (Table 5) of the drivers in the densely populated Paris area could have conducted their daily activity schedule using modes other than the car with the same, or a lower, travel time-budget. 8% of drivers therefore chose the car for reasons other than travel speed. The great majority of them did not choose the car for economic reasons either: more than 80% of them would have saved a considerable amount of money if they had used a different mode. They chose to travel by car, for example, on the grounds of comfort, because of the individual passenger compartment, because of a lack of knowledge about the alternatives or because they do not trust them, etc. In the reference situation, these drivers represent a potential reduction in automobile traffic (in vehicle-kilometres term) in the zone of about 4%. We have also come to understand that a large-scale reduction in car use can only be marginally assisted by reducing car use which is ‘irrational’ in terms of time, if the same activity schedule are retained. On the grounds of symmetry it is apparent that 92% of drivers could not have performed their daily activity schedule otherwise than by car.

Table 5: Potential amounts of transferable travel in reference scenario

Constant travel-time-budget and constant public transport supply		
Percentage transferred	**Paris conurbation HP-HC 90**	**Lyon conurbation HP95**
Round trips	7.2%	14.2%
Trips	6.5%	12.5%
Vehicle-kilometres	4%	6.1%
Persons	8%	18.1%

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

In the Lyon conurbation, the percentage of drivers who could not have performed their daily activity schedule otherwise than by car without altering their travel-time-budget is lower than that in the densely populated part of the Greater Paris Area (82%). It is thus apparent that the greater the broad constraints that operate against car use (congestion, trip time irregularities, parking problems etc.), the lesser the extent to which car use behaviours are “irrational” in terms of trip times.

The other important result from this first iteration relates to the modal split of the trips which could potentially be transferred: with constant public transport supply and constant individual travel-time-budgets, public transport would take 66% of potentially transferable round trips and 95% of the vehicle-kilometres travelled while making them. Walking, whose market has been assumed to involve round trips of less than 2 kilometres, only takes 8% of potentially transferable trips and the bicycle, whose market involves round trips of less than 8 kilometres, 26%. These two personal modes are only responsible for 5% of the reduction in automobile traffic (in vehicle-kilometres terms). Apparently, in the densely populated Greater Paris Area, although the problem of modal transfers can involve the familiar attempt to transfer short trips to walking or cycling which are effective modes for them, the result is relatively marginal reductions in automobile traffic.

In the Lyon conurbation, the market of potentially transferable trips is structured in a very different manner: although walking is no more prevalent than in the densely populated Greater Paris Area, the bicycle is potentially the most important mode involved, taking 66% of the potentially transferable automobile round trips and 41% of the vehicle-kilometres. Public transport represents only 28% of the potentially transferable automobile round trips but 57% of the vehicle-kilometres. Even, if public transport is the first mode in vehicle-kilometres terms, this results demonstrate that in the Lyon region the issue of modal transfers and automobile traffic involves strategies that are located on a different scale than in the densely-populated Greater Paris Area.

Now the issue of modal transfer in the study zone has been more clearly stated we shall turn to the main purpose and interest of this research which is to demonstrate how the potential for modal transfer can be augmented and to identify the break with the past which would shape a radically different future.

3.3. Potentially transferable travel and increase in the travel time-budget

We have demonstrated that with a constant public transport supply, if an increase in individual travel time-budgets is accepted (rules 9-11), the amount of potentially transferable travel doubles (Table 6). Under these circumstances, modal transfer would affect about 16% of initial automobile round trips and the reduction in vehicle-kilometres would be about 9% in the case of Paris (26% and 13% in the Lyon case). 20% of the drivers in Paris area would be involved (32% in the case of Lyon), slightly more than half of whom would be subjected to an increase in travel time after transfer by an average amount of 12%, and 43% of whom would save time. In terms of modal share, public transport is still dominant in the Paris conurbation. For the Lyon conurbation, the bicycle’s share decreases to the benefit of public transport, which accounts for two-thirds of vehicle-kilometres, because the increase in travel time-budget allows longer rounds trips to be transferable.

In the Parisian context, if a doubling of travel time-budgets is permitted, the amount of potentially transferable travel would increase to 38% of initial automobile round trips and 20% of the number of vehicle-kilometres. The difference between the reasonable hypothesis (rules 9-11) and the less realistic doubling of travel times is only a gradual increase in the amount of transferable travel, which fails to overcome the problem. Imposing constraints on travel speeds under the reference conditions has a non-negligible potential for stimulating modal transfers. However, the level of constraint that is required to achieve a potential reduction of between 30 and 50% of the initial vehicle–kilometres is such that it would seem necessary to accompany this sacrifice with regard to initial speeds by a forceful policy to improve transport supply.

Table 6: Potential amounts of transferable travel with constant public transport but increase in travel-time-budget

Increase in travel-time-budget tolerated (Cf. rules 9-11) and constant public transport supply		
Percentage transferred	**Paris conurbation HP-HC 90**	**Lyon conurbation HP95**
Round trips	16.2%	25.5%
Trips	13.1%	21.9%
Vehicle-kilometres	9%	13.4%
Persons	19.2%	32.1%

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

3.4. Potentially transferable trips with an increase in travel time-budget and an improvement in the public transport system

The simulations we have conducted on the basis of major increases in public transport and a hypothesis of an increase in the travel time-budgets of drivers (rules 9-11) on Paris conurbation, give results which differ quite markedly depending on the configuration of supply. The restructuring of supply which provides the greatest potential modal transfer in the study zone is to impose a constant bus frequency of 4 minutes throughout the day and to increase the commercial speed by 30% on the 60 main bus routes in the Paris and Inner Suburban network. This restructuring is that described in the "Mobilien" configuration (Cf. section 2.3) which was first featured in the Urban Travel Plan for the Paris area. It increases potential transfer of initial automobile round trips to 20% and reduces the number of vehicle kilometres by 12.5% (Table 7). The most ambitious supply scenario with an increase of about 44% in seat kilometres, which is referred to as [HP 2010 + Mobilien + 15,20,25] places the rail network at the centre of the transport system. It results in only a very slight increase in potentially transferable travel over the previous "Mobilien" scenario (about 21% of initial automobile rounds trips). But when it is combined with accompanying strategies (scenario HP2010 Mobilien + 15,20,25 + accompanying strategies, Cf. section 2.3), the growth of rounds trips transferable is important (+ 5.6%). The growth in terms of vehicle-kilometres is of the same magnitude. It seems therefore that the potential effect of heavy public transport system is much more important when it is combined with accompanying measure like park and ride and information. This amply confirms the hypothesis that is widely held in professional circles, namely that a change towards a different future can only occur if synergy is achieved between "combined" actions.

With the public transport scenario for the year 2010 in the Lyon conurbation (scenario HP2010 PDU, Cf. section 2.3), the number of transferable round trips increases by approximately the same percentage as in the Paris conurbation (Table 7). The same applies to the number of trips and the number of persons involved. However, as the transfer mainly involves quite long round trips, the increase in the number of transferred vehicle-kilometres is greater. If we take the increase in public transport supply as far as possible in the light of existing rail infrastructure in the conurbation and by providing exclusive bus lanes for all bus routes from other traffic (scenario HP2010+rail+15,20,25 with a doubling of seat kilometres, Cf. section 2.3), the increase in the number of transferred round trips is very small in comparison with the previous scenario, as in the Paris conurbation. However, the increase in passenger kilometres is still greater, which makes one think that the transferred round trips are longer than average, as in the Paris conurbation.

Table 7: Potential amounts of transferable travel for each public transport supply scenario

Increase in travel-time-budget tolerated (Cf. rules 9-11) and growth of public transport supply					
Percentage transferred	**Paris conurbation**			**Lyon conurbation**	
	HP 99 + Mobilien	HP 2010, Mobilien +15,20,25	HP2010 Mobilien + 15,20,25 + accompanying strategies	HP2010 PDU	HP2010+ rail +15,20,25
Round trips	20.3%	21.1%	26.8%	30.1%	32.2%
Trips	16.5%	17.2%	27,5%	26.5%	28.4%
Vehicle-kilometres	12.6%	13.3%	18,5%	18.8%	22.9%
Persons	23.8%	24.5%		37.6%	40.2%

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

From a spatial point of view, this scenario results in a considerable transfer of round trips with radial trips and round trips which are located in the most central areas of the conurbation (Lyon, Villeurbanne, Cf. map 1). As in the Paris conurbation, the most ambitious scenario is relatively successful in achieving the transfer of radial round trips as a result of an increase in rail services which are mainly radial. Similarly, in the most central zones, there is a further increase in the already high proportion of round trips that are on public transport. The improvement in the performance of public transport results in large scale transfers because of the inefficiency of the car in these dense areas. However, in the suburbs and especially the most distant suburbs, public transport is probably not flexible enough in view of the high speeds achieved by cars. An extension of heavy public transport infrastructure (metro or rail) is not able to satisfy ever-increasing internal travel demand within peripheral areas. The poor match is in most cases made worse by the fact that suburban bus services have been reorganised to provide feeder services to heavy public transport routes instead of services between different districts.

3.5. Potential amounts of transferable travel relaxing activity rules

The most ambitious scenario [HP 2010 + Mobilien + 15,20,25 + accompanying strategies] and the relaxing of the rules on shopping and escorting activities (rules 5 and 6), results in a non-negligible amount of travel that is potentially transferable from the automobile to environmentally-friendly modes (Table 8). In Paris region, this potential involves 34% of car trips on a given day, 33% of trips, 23% of car passenger-kilometres and 38% of car drivers. In Lyon region, the growth is even more important.

From previous results (Table 7), it appears that if the growth in rounds trips is quite significant, the effect on vehicle-kilometre is not of the same importance. This rounds-trips are shorter than those already transferred. This shorter distance explains that the transfer is much more important in Lyon conurbation, where a lot of this rounds-trips match the distance of the bicycle market, which is not so much the case in the Paris region. Again we can observe the effect of the size of the conurbation on the transfer.

Table 8: Potential amount of transferable travel for each of the full scenarios (public transport supply + accompanying strategies + relaxing activity rules)

Increase in travel-time-budget tolerated (Cf. rules 9-11), growth of public transport supply + relaxing activity rules (rules 5, 6)		
Percentage transferred	**Paris conurbation** HP2010 Mobilien + 15,20,25 + accompanying strategies	**Lyon conurbation** HP2010+ rail +15,20,25
Round trips	34%	47%
Trips	31%	43%
Vehicle-kilometres	23%	31%
Persons	38%	53%

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

3.6. Synthesis of transfer procedures

The sequence of different simulations allows us to draw some conclusions about the effects of each of the measures on the potential number of round trips that are transferable.

The first thing is that current car usage is, with regard to trip time, generally very rational (only 4% of driver vehicle-kilometres could be transferred to other modes with the same travel time budget in Paris and 6% in Lyon (Table 9). Increasing travel time-budgets allows this potential to be doubled, but it is still very small. Increasing travel time-budgets cannot reduce the dominance of the car.

An increase in public transport supply, no matter how great, in the two most ambitious scenarios in both conurbations (an increase in seat kilometres of 44% in Paris and 92% in Lyon) is not able to achieve a drastic decrease in the dominance of the car either. Its effect is similar to that of an increase in travel time-budgets. However, the scale of the effect of accompanying measures (feeder trips by bicycle or by car and effective information strategies allowing users to reduce their waiting times) is perhaps surprising. The effects are of the same order of magnitude as an investment in heavy public transport systems.
Lastly, the impact of removing the constraints that apply to weekly or exceptional shopping activities or escorting trips is of the same order of magnitude as the measures described above. However, unlike the previous measures, they will probably require individuals to reorganise their activity schedules or an increase in delivery services for purchases.

The impact of each of the simulated measures in isolation is therefore limited. While the individual’s sacrifice and the social costs for each measure differ, at this stage we can state that in combination they could lead to a significant modal transfer.

Table 9: Synthesis of the impact of the different simulation strategies on car vehicle-kilometre transferred

Simulation hypothesis	Potential reduction in car traffic (vehicle-kilometres)	
	Paris conurbation	**Lyon conurbation**
Constant individual travel time budget Constant supply	4%	6.1%
Time-budget increase margin (rules 9-11) Constant supply	9%	13.4%
Time-budget increase margin (rules 9-11) Highest transport supply	13.3%	22.9%
Time-budget increase margin (rules 9-11) Highest transport supply Accompanying strategies for public transport supply	19.6%	
Time-budget increase margin (rules 9-11) Highest transport supply Accompanying strategies for public transport supply Removal of activity constraints	23%	31%

Sources: INRETS, based on the Comprehensive Transport Survey - EGT (DREIF) 91-92
LET, based on the Household Travel Survey 94-95

This potential involves, in the most ambitious full scenario, 34% of car trips on a given day, 31% of trips, 23% of car driver-kilometres and 38% of car drivers in the Paris Region (and 47% of car trips on a given day, 43% of trips, 31% of car driver-kilometres and 53% of car drivers in the Lyon conurbation). Over the entire zone, the percentage of trips that are by car would fall from 36% to 25%, i.e. a drop of 11 percentage points of modal share, which can be considered to be significant (in Lyon, the share drops of 18% from 54 to 36%). Public transport takes 80% of the transfers, and its share of trips would rise from 26.3% to 35.1%, which represents an increase of some 1.9 million public transport trips per day, which is significant too; the bicycle's share of trips would increase from 0.4% to 2.1% (in Lyon, public transport takes only 56% of the potential transfer growing from 13 to 23% of the trips market and the bicycle 43% of the potential transfer with a share which evolves from 0.6 to 9%). As the result of the size of the conurbation, the bicycle's market share in the Paris conurbation is extremely small. This is not the case in Lyon. In smaller urban areas, the bicycle can only be more appropriate. It should nevertheless be borne in mind that in Lyon, although a significant percentage of trips are by bicycle, its role is much more modest in terms of vehicle-kilometres. An increase in public transport is therefore an inevitable part of the set of measures that must be implemented to reduce the car's dominance in cities.

Furthermore, in Paris region, the analysis we have conducted of the most ambitious full scenario has demonstrated that strategies which involve the transfer of some or all travel would result in gains in terms of travel-time-budget and/or money for 67% (77% in the Lyon case) of the drivers involved. However, 33% (23% in the Lyon case) of drivers would have difficulties in making a modal transfer: among them the large majority would lose time and money and/or would be unable to make the transfer without putting at risk the travel of one or more third parties (the passengers they take in their cars). We feel that these few items of data show that the sacrifice required of many drivers is limited and very possible in view of the fact that the monetary gains are considerable and the time losses virtually negligible. In straightforward terms a policy that reduces car use would not penalise these drivers, as long as public transport pricing unchanged.

The figures we have given above, which of course only refer to potential changes, allow us to measure the “realm of the possible”. The potential changes are not marginal, even if it is true that the envisaged measures (which are very consequent and very costly) do not change the situation of 62% of drivers and 77% of car traffic (in terms of vehicle kilometres for Paris region). This “realm of the possible” also provides a non marginal reduction in energy consumption and pollutant emissions. It does, however, pose a problem of social acceptability in that the sacrifice in terms of transferred vehicle-kilometres is distributed among a small fraction of the drivers involved. For example, for employed persons, the average time sacrifice required of senior managers and the intermediate professions is greater than that required of workers; in addition, the big winners are over-represented among the population of Paris and the big losers are over-represented in the inner suburbs where the potential for effective alternative modes is lowest.

It emerges from this analysis that although it is possible to design policies which reduce car usage without seriously modifying the activities and travel time of the great majority of drivers, the distribution of winners and losers and the sacrifices that are demanded within society in order to produce these transfers are likely to give birth to a debate on the social acceptability of policies to reduce car use and the measures which are necessary to make the policies more tolerable, or even more “politically acceptable”.

Achieving anything more than a 25% vehicle-kilometre reduction in the Parisian context (30% in the Lyon context) in simulation would certainly require measures and approaches which cannot be part of our methodology as described here. More ambitious objectives with regard to car use reductions could be achieved by introducing tradable riding permits. A recent forward study (DRAST, 2000) is based on the hypothesis that this would only be feasible in the event of a major environmental crisis. In any case, it could not be introduced without threatening individual activity schedules, localisation patterns, travel speeds, transport players and services as our procedure has demonstrated that present-day alternatives to the car have limits in the context of a less ambitious scenario.

4. Conclusions

When constructed gradually and on the basis of measures that are familiar (at least as of ideas), the changes to the transport system that result from the simulations we have conducted may appear to be very much in line with current trends, and not “radically different” in the way one might expect from more radical technical and organisational innovations. However, we consider that such technical, organisational and political innovations are implicit in these scenarios: thus, providing the technical means of increasing bus speeds by 30% on narrow roads is an innovation which does not only depend on how road-space is shared, but also limiting waiting times at station and ensuring reliability of transport public services.

In our opinion, a “radically different” future is to be found in the creation of synergies between measures and the relevant players in order to achieve a reduction in car use. The objective of achieving a 25% reduction in car vehicle-kilometres is possible without really placing the activities and travel times of the great majority of drivers at risk, and without threatening the siting patterns and vested interests of organisations, in particular transport undertakings. A “radically different” future is to be found in the debate that must take place with regard to actions that are clearly identified and whose consequences have been measured. Our research is clearly part of the opening of this debate. Although the measures have not been located very precisely in space and although we have had to use data from the 90s as none more recent are available, the validity of the methodology we have developed for this purpose has been demonstrated.

Bibliography

Bonnel P (2000), Lyon 21, *Etude de faisabilité d'un système radicalement différent pour l'agglomération lyonnaise*, LET/INRETS, Lyon.

Bonnel P, Caubel D, Mignot D (2002), *Etude de faisabilité d'un système de transport radicalement différent pour la zone dense lyonnaise*, Laboratoire d'Economie des Transport, Lyon, 130p.

Boulahbal M (1995), *Le chaînage des déplacements: interface entre activité et mobilité individuelle*, - Mémoire de DEA, ENPC - Université de Paris 12, Paris.

CERTU (1998), *L'enquête ménages déplacements « méthode standard »*, Collections du CERTU, éditions du CERTU, Lyon, 295p.

CETE de Lyon, INSEE, SYTRAL (1995), *Enquête « déplacements auprès des ménages de l'agglomération lyonnaise »*, document technique, Lyon, 119p.

DREIF (1995), *Les transports de voyageurs en Île-de-France*, Préfecture de l'Ile-de-France, Paris

DREIF (2000), *Le Plan de Déplacements Urbains d'Ile-de-France*, La documentation Française, Paris

Crozet Y, Orfeuil J-P, Massot M-H et le « groupe de Batz » (2001), *Mobilité urbaine: cinq scénarios pour un débat*, Note du CPSV, N°16, DRAST, Paris La Défense.

Gallez C, Polacchini A (1996), *Budgets énergie environnement des déplacements dans l'arrondissement de Lille*, Rapport de Convention ADEME/INRETS N° 690-9306-RB, Arcueil.

Gallez C, Orfeuil J-P (1997), *Politiques locales et maîtrise des déplacements en automobile: analyse des potentiels de régulation*, Rapport INRETS, Arcueil.

Jones P (1990), *Developments in Dynamic and Activity-Based Approach to Travel Analysis*, Oxford Studies in Transport, Avebury Edition.

Massot MH, (1999), *Pari 21, Etude de faisabilité d'un système de transport radicalement différent pour la zone dense francilienne*, Programme de recherche INRETS, Arcueil, 20 p.

Massot M-H, Armoogum J, Hivert L (2000), *Pari 21, Etude de faisabilité d'un système de transport radicalement différent pour la zone dense francilienne*, Programme de recherche INRETS, Arcueil, 100 p.

Massot M-H, Armoogum J, Hivert L (2002), *Pari 21, Etude de faisabilité d'un système de transport radicalement différent pour la zone dense francilienne*, les collections de l'INRETS, Rapport INRETS n° 243, Arcueil, 198 p.

Mackett RL, Robertson SA (2000), *Potential for mode transfer of short trips: review of existing data and literature sources*, Centre for Transport Studies, University College London, London.

Schafer A (2000), Regularities in travel demand: an international perspective, *Journal of transportation and Statistics*, Vol. 3 N°3, pp. 1-31.

SYTRAL (1997), *Le plan de déplacements urbains de l'agglomération lyonnaise*, Sytral, Lyon, 66p.

Wiel M (1999), La transition urbaine ou le passage de la ville pédestre à la ville motorisée, MARDAGA, Col. Architecture + Recherches, Sprimont (Belgique), 149p.