Analysis of principal trends of mobility related to location policy, car ownership, supply policy and ageing of the population

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1. Focus/Research area/Why is the topic important?

The growth of car ownership (Dargay, Gately, 1999) and daily use of cars (both in terms of number of trips, and average distance per trips) is a major trend of the European and North American cities during the last decades (Nijkamp, 1993), and they are still growing, due to multiple factors. The sustainability of the model of urban development based on car mobility is more and more questioned (Bonnel et al., 2002): increasing road congestion, problems with public transport financing (Raux, 1996), and still more important, environmental degradation, both on local and global dimensions. If we can expect that technological improvements of vehicles and fuel could reduce or at least stabilise local emissions of pollutants in the future, all studies agree that greenhouse effect will continue to growth caused in particular by the important increase of car use (Banister, 1998, Nicolas, 2000).

This context leads to a growing interest for more sustainable transport policies. Analysis of urban travel policy developed in Europe (Bonnel, 1995) indicates that even if some interesting results have been obtained, there is still a strong need to analyse the ways to reduce car use. For example in Lyons (France), despite an investment of more than 2 billion of Euro to develop public transport supply between 1976 and 1995, the share of public transport against private car has remained stable. Furthermore this stability in term of share is also synonymous of a dramatic increase in car vehicule*kilometers: it nearly increased twofold during the same period (Bonnel et al., 2002).

We therefore need to analyse more deeply the factors which contribute to this growth. Growth of income and car ownership, but also demographics effects and urban sprawl of residences and of economic activities are amongst the most explicative factors of this global trend (Banister, Bayliss, 1992; Kostyniuk, Kitamura, 1987 ; Pochet, 1995). But the quantification of the effect of each factor is uneasy, due to the multiple correlations of the dynamics of these factors on mobility. Therefore cross section analysis often fails to understand long term evolutions. This difficulty may explain, for example, why planners generally underestimate the number of car trips that future generations will make in their 70's and 80's, and consequently, their environmental impact (Rosenbloom, 2001). To analyse complex evolution of mobility over time, diachronic data are necessary, as well as methods to separate the effects of correlated and changing explanatory variables.

2. Context/Status quo and future developments

In this paper, we present such a method (on an aggregate or semi-aggregate basis) in order to breakdown effects of different factors on the evolution of mobility indicators. Two examples of application of this method show interesting results. The interrelations between the factors appear to be negligible. The influence of each factor can be separated from the other ones, and therefore can be estimated.

We present the formulation of the method with only two factors, but it can be generalised without any difficulty, except the written form of the equation. Let us begin by explaining the notation:

Y is the factor to be explained;

a and b are two explanatory variables;

F is a function applying to the explanatory variables: $Y= F(a, b)$ (1)

The change in Y between two given dates (date 1 and date 2) is therefore expressed as follows:

$$\frac{Y_2}{Y_1} = \frac{F(a_2,b_2)}{F(a_1,b_1)} = \frac{F(a_2,b_1)}{F(a_1,b_1)} \times \frac{F(a_1,b_2)}{F(a_1,b_1)} \times \frac{\frac{F(a_2,b_2)}{F(a_1,b_2)}}{\frac{F(a_2,b_1)}{F(a_1,b_1)}} = E(a) \times E(b) \times E(a,b) \qquad (2)$$

- where E(a) denotes the effect of factor a on its own. It is a rate of absolute variation obtained by varying this factor between date 1 and date 2 while keeping all other elements constant: $E(a) = \dfrac{F(a_2, b_1)}{F(a_1, b_1)}$;
- E(b) denotes the effect of factor b on its own. It is a rate of absolute variation obtained by varying this factor between dates 1 and 2: $E(b) = \dfrac{F(a_1, b_2)}{F(a_1, b_1)}$;
- E(a, b) denotes the double effect of factors a and b. It is the ratio between two rates of absolute variation (the first rate corresponds to the effect of factor a when factor b is in state 2 and the second corresponds to the effect of factor a with factor b in state 1): $E(a,b) = \dfrac{F(a_2,b_2)}{F(a_1,b_2)} \Big/ \dfrac{F(a_2,b_1)}{F(a_1,b_1)}$.

We are thus able to break down the overall rate of variation into 3 effects, two single effects caused by the variation of each factor in isolation and one double effect depending on the variation of the two factors. The objective is obviously to obtain a double effect that is equal to or very near 1 such that the change in Y can be regarded as being the product of each of the effects in isolation.

We then present two examples of application of this method to quantify the effect of socio-demo-economics factors on share of public transport and car use.

2.1. Effect of activity location, car ownership, transport supply on public transport share

The above method is applied first to the change in the modal share of public transport (among motorised trips) in Lyons conurbation between 1976, 1985 and 1994, according to changes in location of activities (factor l), car ownership (mot), transport supply both public (pt) and private (pc) and evolution of other factors (a). We therefore have 5 explicative factors.

The variation in public transport share $\frac{P_{PT2}}{P_{PT1}}$ is expressed as:

$$\frac{P_{PT2}}{P_{PT1}} = \frac{F(l_2, mot_2, pc_2, pt_2, a_2)}{F(l_1, mot_1, pc_1, pt_1, a_1)} = E(l) * E(mot) * E(pc) * E(pt) * E(a) * residual \quad (3)$$

The residual contains 26 factors: 10 double effects when 2 factors interact, 10 triples, 5 quadruples and 1 quintuple effects. To explain the evolution of the share of public transport as the product of five simple effects, we need to have the 26 residual factors as close as possible to 1. This is done with a particular definition of each variable which reduces the correlation between the evolution of each variable. From this definition, we have expressed the share of public transport (P_{PT}) using a logit expression:

$$P_{PT} = \sum_{ij} l_{ij} * P_{PTij} = \sum_{ij} l_{ij} * \frac{1}{1+e^{g(mot_{ij}, pc_{ij}, pt_{ij}, a_{ij})}} \quad (4)$$

where l_{ij} is the proportion of all car and public transport trips that is on the origin-destination pair in question;

P_{PTij} is the market share of public transport for the origin and destination pair i/j;

mot_{ij} is car ownership for trips between i and j;

pc_{ij} is the generalised cost by car of trips on the origin-destination pair i/j;

pt_{ij} is the generalised cost by public transport of trips on the origin-destination pair i/j;

a_{ij} is the “other factors” term for the origin-destination pair i/j;

and $g(mot_{ij}, pc_{ij}, pt_{ij}, a_{ij})$ express the difference of utility of both modes of transport: car and public transport for the origin-destination pair i/j.

The function g has been calibrated on the three households surveys conducted in Lyons during last twenty years: 1976, 1985 and 1994. We have tested several utility functions

(Bonnel, Cabanne, 2000). We present the results for the simple one which is a usual linear-in-parameters function. Application of the equation 3 allows to estimate single and correlative effects (Table 1).

Table 1: The Impact of the different factors on share of public transport

Period over which impacts have been computed	Whole period (1976-1994)	1976 – 1985	1985 – 1994
Overall growth	2.6%	13.2%	-9.4%
Simple Effects			
Impact of activity location w(l)=E(l)-1	-8.6%	-3.9%	-6.5%
Impact of car ownership w(mot)=E(mot)-1	-12.7%	-11.7%	-1.1%
Impact of private car supply w(pc)=E(pc)-1	5.2%	1.1%	3.9%
Impact of public transport supply w(pt)=E(pt)-1	10.1%	7.1%	2.5%
Impact of the "other factors" w(a)=E(a)-1	11.7%	21.6%	-8.7%
Product of the 26 correlative effects (residual of equation 3)	-0.3%	1.3%	0.8%

Data Source : Lyons conurbation travel household surveys 1976, 1985, 1994.

Reading: the overall growth between 1976 and 1994, of +2.6% (1,026), is equal to the product of the different factors, i.e. activity location factor (0.914 or -8.6%) multiplied by car ownership factor (0.873 or –12.3%) multiplied by… etc. It means for instance that, all factors staying equal, the impact of activity locations factor would have led to a decrease of 8.6% in the share of public transport.

Over the period 1976-1994, the effect of location can be estimated at -8.6%. The effect appears to have been more important during the second period (-6.5%) than during the first one (-3.9%). The location factor was defined as the matrix of the proportion of trips on each origin-destination pair. The "location" effect is therefore not exactly the impact of urban sprawl, but can be seen as a consequence of urban sprawl and individual location choices.

We can estimate the effect of car ownership growth at -12% over the first period. With regard to the second period (1985-1994), the origin-destination matrix of car ownership has remained almost stable, leading to a very small effect. The effect of car ownership corresponds to the definition of the origin-destination matrix of car ownership (the car ownership on an origin-destination is the average of the car ownership of each trip made on the origin-destination). Therefore we have not measured the full effect of the change in car ownership over the entire conurbation. What we have done, in a way, is to break down the change in car ownership into two factors: the change in car ownership in the context of a given spatial structure and the change in car ownership linked to change in the spatial structure of flows. The effect of car ownership that we measured is therefore limited to the influence of the first factor, while the second is included among the effect of location.

We estimate the impact of transport supply at 16% over the whole period. Transport supply has been defined on the basis of the generalised cost of public transport and the car. The impact of parking difficulties has been excluded from this as we do not have data for the three survey dates. As a result this has been included among the "other factors". The effect of transport supply can be split between the two modes. The considerable improvement in public transport supply during the period (the construction of four metro lines, restructuring of the bus network, large increase in vehicle/kilometres, etc.) has led to a reduction in the generalised costs of public transport which explains the 10% increase in its market share, all other factors staying equal. Increased car use combined with increased distances travelled has been responsible for a fairly moderate increase in the generalised costs of car transport as a result of improvements to the network and traffic control measures. This limited increase has contributed to a growth of 5% of the share of public transport during the period 1976-1994.

We have also shown the importance of the impact of the "other factors". The values of the different effects should be considered in terms of orders of magnitude, but the "other factors" would seem to have as much influence as the various explanatory factors and seem to have been responsible for altering the direction of a trend. The increase in the modal share of public transport would seem to be greater than expected in the first period, but in the second one, other factors seem to have restrained this increase. Several possible reasons can be given for this. The "marketing" effect of the opening of the metro in 1978 could have increased the attractiveness of public transport to a greater extent than the increase in services would justify, and the extension of the network after 1985 failed to have a similar effect. Between 1985 and 1994 policies aimed at increasing parking supply in the centre of the conurbation could have contributed to reduce the modal share of public transport, as could the increasing complexity of journeys as compared with straightforward home-based return journeys. Finally, perhaps a change in behaviour is taking place stemming from a perception of transport modes which tends to favour the car, which the stable generalised cost functions over the period as a whole has not been able to express.

2.2. Effect of demographics, car ownership and behaviour on car use

The second example is the change in total volume of trips as car driver over time, according to ageing of the population and to cohort related effects (growing motorisation and increasing reliance on car). The relevant question for the future of the changes in mobility of the elderly population has been the subject of several studies in Western Europe and North America (see for example, Brög et al., 2000, Bussière et al., 1996, Hjorthol and Sagberg, 2000, Pochet, 1995, 1998a, Rosenbloom, 2000, 2001, Wachs, 1976); changes appear to be of various amplitude according to the countries, but are generally remarkably large, especially as far as the use of car is concerned. In order to be able to highlight the different effects in the evolution of car-driver mobility, the following example aims at breaking the increase in this indicator into different factors.

We have divided up the total volume of car–driver trips by age group, according to three components as follows: the weight of each age group, the proportion of motorised persons in each age group, and the mean number of daily trips made by motorised individuals at the wheel for each age group (Greene, 1987). The evolution in the use of the car as a driver

(*CD2/CD1*) between date 1 and date 2 is therefore a ratio of the two sums of number of trips for all age groups *i*:

$$\frac{CD_2}{CD_1} = \frac{\sum_i P_{i2} C_{i2} M_{i2}}{\sum_i P_{i1} C_{i1} M_{i1}}$$

with P_{i1}, P_{i2}: relative number of people in age-group *i* in dates 1 and 2;

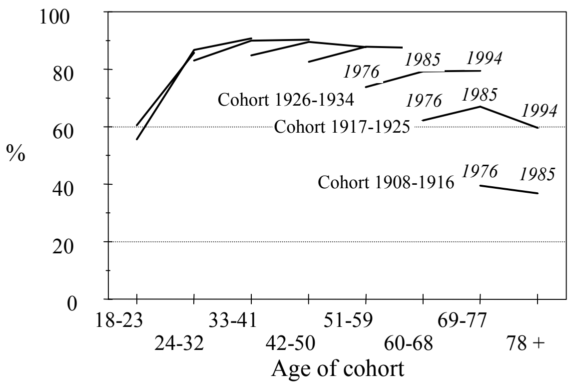
C_{i1}, C_{i2}: percentage of motorised individuals in age-group *i* (i.e. licence-holders whose household owns at least one car) in dates 1 and 2;

M_{i1}, M_{i2}: mean number of daily trips made by motorised individuals at the wheel in dates 1 and 2.

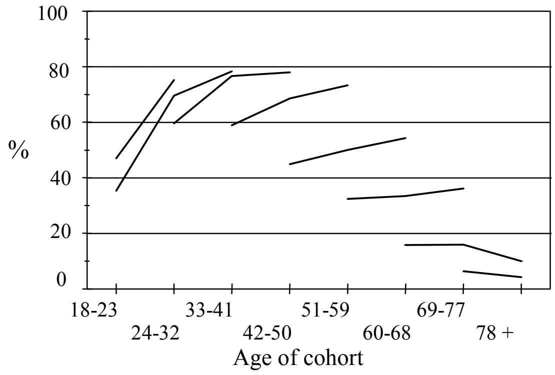
This breakdown can be made for the whole population, or divided by gender, and for a particular age group (for instance, if we want to target the cohort effects among the elderly, we can apply it on the sixty and over, etc.). The distinction between men and women is necessary, especially for the elderly, because, historically in France as in other countries, men became car drivers well before women, the access to car of women being linked to their own professional activity (see Wachs, 1987, for the USA). These gender differences in cohort effects appear clearly on Figure 1a and 1b.

Figure 1: Evolution in the proportion of motorised individuals(*) in each cohort in Lyons between 1976, 1985 et 1994 (%)

a- Men



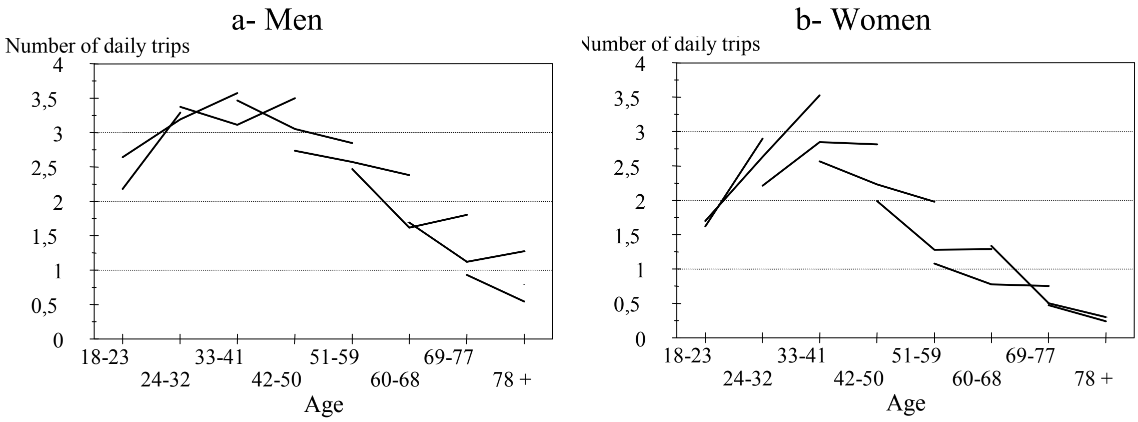
b- Women



***Motorised individuals**: individuals of 18 and more, with a driver licence and belonging to a household owning at least one car.

Through these figures, important cohort effects on car ownership can be seen. Amongst women, the differences in car ownership and access to car between generations are especially high for cohorts today aged of forty and more, i.e. between the generations born in the twenties, thirties and forties. Cohort effects can also be seen in the use of car by motorised women, which are more and more relevant among the successive generations (Figure 1b and 2b). Amongst men, as far as car ownership and daily use of car by motorised persons are concerned, cohort effects are concentrated on the ancient generations, those born before, or during, the twenties, who are currently aged of sixty and more (Figures 1a and 2a).

Figure 2: Evolution in the mean number of car trips as driver of the motorised individuals* of each cohort in Lyons between 1976, 1985 et 1994



* **Motorised individuals**: individuals of 18 and more, with a driver licence and belonging to a household owning at least one car.

The results are the following, for the 18 and over and for the 60 and over (Tables 2 and 3). We verify that double and triple effects are minor. The overall growth can be explained by the three simple effects. The first result is the preponderance of two effects in the overall evolution: on one hand, the changes in car ownership and in licence-holder rates and, on the other hand, the change of behaviour. For men as for women, the « car ownership effect » (ie effect of increase of the percentage of motorised individuals, all other factors staying equal) is stronger in the earlier period (1976-1985) than in the latter one (1985-1994), period when « behaviour effect » (ie effect of increase of the mean number of car trips of motorised individuals, all other factors staying equal) is getting stronger. Except for older women, there is a saturation in the access to car (at least in the way that we defined this access to car). These results globally confirm those established on another French conurbation, Grenoble, between 1978 and 1992 (Pochet, 1998a).

The consequences of development of multi-motorisation should also be taken into account. The multi-motorisation enables a growing individualisation in the daily use of car, and therefore explains a part of the influence of what we called « behaviour effect ». The "demographic" effect E(P), equal to the variation between dates 1 and 2 (where all the other variables have no incidence) of the proportion of people in each age-group, appears very limited. Even with the large demographic changes to come, we cannot hope that the ageing of population will significantly reduce the overall use of car, because the behaviour of future cohorts of elderly will still certainly be closer to those of the younger adults than today.

Table 2: Breakdown of Car Driving Growth for Men and Women of 18 and Over

	Men			Women		
	1985/ 1976	1994/ 1985	1994/ 1976	1985/ 1976	1994/ 1985	1994/ 1976
Overall growth	+3.9%	+15.6%	+20.1%	+43.9%	+41.8%	+104%
Simple Effects						
Evolution of Demographic structure Effect	-3.2%	0.0%	-3.3%	-2.9%	-0.7%	-0.1%
Evolution of Car ownership Effect	+9.8%	+1.1%	+11.0%	+34.1%	+15.7%	+50.0%
Change in Behaviour of Motorised Individuals Effect	-2.8%	+13.4%	+10.2%	11.5%	+17.6%	+36.7%
Product of the four Interaction Effects	+0.5%	+0.9%	+1.5%	-0.9%	+1.2%	-0.5%

Data Source: Lyons conurbation travel household surveys 1976, 1985, 1994. **Reading**: see Table 1

Table 3: Breakdown of Car Driving Growth for Men and Women of 60 and Over

	Men			Women		
	1985/ 1976	1994/ 1985	1994/ 1976	1985/ 1976	1994/ 1985	1994/ 1976
Overall growth	+30%	+79%	+133%	+49%	+186%	+326%
Simple Effects						
Evolution of Demographic Structure Effect	-2%	+1%	0%	+8%	+2%	+10%
Evolution of Car ownership Effect	+34%	+14%	+54%	+116%	+74%	+276%
Change in Behaviour of Motorised Individuals Effect	-1%	+54%	+51%	-36%	+62%	+3%
Product of the four Interaction effects	+0%	+1%	+1%	+0%	-1%	-1%

Data Source: Lyons conurbation travel household surveys 1976, 1985, 1994. **Reading**: see Table 1

As we see, the context is neither favourable to public transport use. As it has been showed in Lyons case, even if public transport is more and more used over time by non-motorised elderly, conversely, the growing motorised elderly population tend to abandon this modal alternative (Pochet, 1998b)

3. Consequences for sustainable transport

This retrospective analysis is interesting in prospective terms. Even if the relationships between the social and economic environment on the one hand and transport demand on the other hand are complex, these two applications show that the global trend is not favourable to public transport. Through the case of Lyons conurbation, it appears that the use of car is getting more and more predominant over time, due to urban sprawl, car ownership, access to car, and renewal of generations. A "modest" objective as keeping the current modal share of public transport, needs large investments in public transport to be fulfilled. Furthermore a status quo in term of modal share is not sufficient to maintain vehicule*kilometre made by car.

But this trend is questionable in term of sustainability. Local pollution will probably reduce due to technological development. But emission responsible of greenhouse effect evolve with an elasticity close to one relatives to car consumption (Banister 1998). Strong improvement in public transport and the necessity to develop the supply in a larger territory due to urban sprawl will increase the need for public funding. Lower efficiency of public transport in less dense area will probably reduce accessibility of people without car which cause equity concern in the most suburban area.

Therefore a sustainable transport policy should develop public transport. But, if it is a necessary condition, it could not be a sufficient condition (Bonnel, 1995). Sustainable plan should also integrates urbanism and locations of activities and residence to reduce or at least control urban sprawl to serve the population by public transport. As urban sprawl continues, sustainable plan should concern larger territory independently of administrative frontier but based on conurbation catchment area. If we need measures to promote modes of transport which respect environment, we will also have to restrict car use in benefit of the other modes of transport.

4. Research questions/Research desirabilities

The quantitative analysis has been done in Lyons. It should be interesting to validate the results on other urban contexts in Europe and US. In both applications, we have analysed the impact on the number of trips per day. It could be interesting to integrate the length of trips, because one part of the recent evolutions in car use come from the increase in distance. In the second application, the formalising of the different effects which we propose only concerns the use of the private car without going into its consequences on other transport modes. In more general terms, both spatial and demographic analysis are presented separately here, although patterns of location and demographics are linked. In particular, the greater and greater reliance on car by the elderly for their daily trips will certainly be reinforced the quite certain, strong ageing of the suburbs in the next decade. The interrelation of the major trends - renewal of generations, demographic ageing, and the distribution of population over space- will certainly cause worries in terms of sustainability. It would therefore be interesting to integrate these two major trends in a joint and simultaneous analysis.

If the diagnostic on the causes of car use increase is quite well accepted, we need to develop analysis of the effects of measures which can be implemented. As causes are multiple, solution should also be multiple. All measures should be integrated in global and comprehensive plan. But we need to develop prospective tools to assess global and comprehensive plan. Especially analysis of the interactions between transport and location need to be developed, in link with the socio-economic and socio-demographic background of such locations. We should also work on the possible way to disconnect car ownership and car use, because in some European countries policy reduction in car ownership are probably not politically acceptable.

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