URBAN SPRAWL AND HOUSEHOLD CAR TRAFFIC GROWTH IN FRANCE : PROJECTIONS TO THE YEARS 2010 TO 2020

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INRETS-DEST

1. INTRODUCTION

High population density is likely to lower car ownership and use. Indeed, alternative transport modes are more widely available in high population density areas compared to less dense ones. Besides, congestion problems may lead to a restrained use of cars, either by users themselves or by specific policy measures. Such an influence on car ownership is clearly evidenced when considering homogeneous zones with respect to population density (Dargay *et al.*, 2000).

In this paper, we investigate the impact of urban sprawl on the long term evolution of household car traffic in France. We draw on a study for the French Ministry of Transport (Berri, 2001). Urban sprawl scenarios are redefined and the projections updated in light of new demographic projections provided by INSEE [1] (2000 edition of Omphale model, based on the 1999 census results).

We analyse household annual car mileage in 10 zones, defined by crossing the criterion of distance to centre with that of conurbation population size, of which one groups rural areas. Using data from repeated cross-sections of the annual INSEE *Household Conjuncture Survey* (1977-94), pseudo-panels are constructed according to the birth year of the household head. Applying an Age-Cohort-Period model, estimates are made for age and cohort effects, along with income and price effects reflecting the general economic context faced by households during the period considered. Relying on the estimated effects and on demographic projections (number of households by age of the head in each zone), we carry out projections of the car traffic generated by households for the years 2005, 2010, 2015 and 2020 according to three scenarios of urban sprawl, in addition to six scenarios of growth of consumption and fuel prices.

2. RECENT TRENDS IN THE CAR FLEET, CAR TRAFFIC AND URBAN SPRAWL

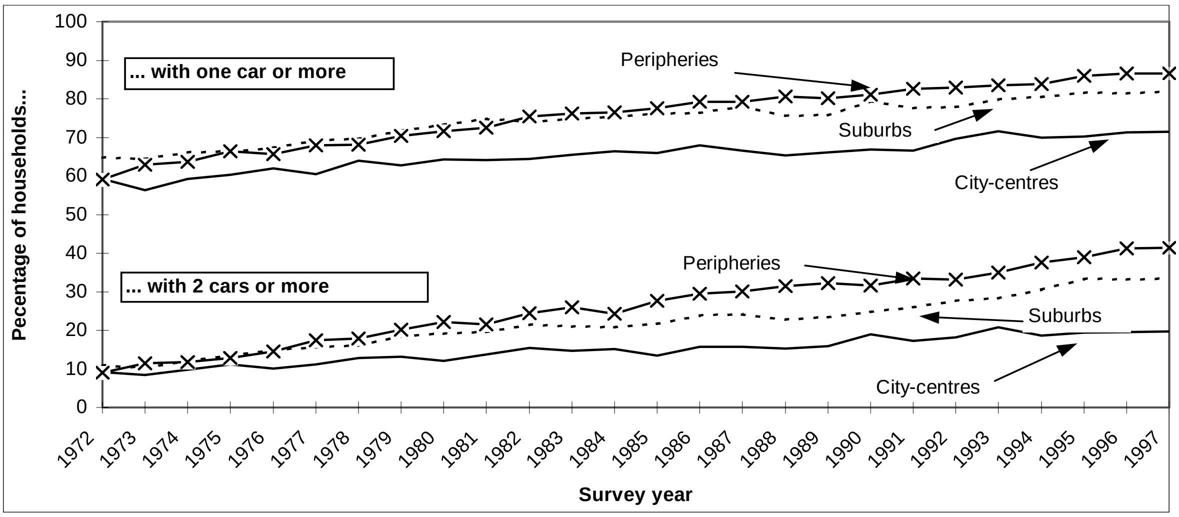
2.1 The Car Fleet and Household Car Ownership

During the last two decades or so, the fleet of private cars continued to increase at a regular pace (an annual rate exceeding 2%, with the exception of two relatively slack periods: 1991-93 and 1995-96), passing from 21 millions at the end of 1985 to 27.5 millions at the end of 1999 [2]. Meanwhile, the fleet saw a progressive change in its structure in favour of diesel (the share of diesel cars passed from 9% in 1985 to 34% in 1999), partly due to a substitution of diesel cars for petrol cars (Hivert, 1999). Combined with an advantageous diesel oil price, this “dieselisation” of the fleet has important consequences on its use. In particular, the replacement of a petrol vehicle by a diesel one is generally accompanied with a strong increase in mileage (Hivert, 1999).

The fleet of utility-type vehicles knew an even stronger growth and a greater movement to diesel: from 3.9 million vehicles (of which 38% of diesel) at the end of 1985, it passed to 5.5 million vehicles (with 76% of diesel) at the end of 1999. Light utility-type vehicles (up to 3.5 tons) represent 90% of the total and their number increased faster than did the whole fleet (45.4% between 1985 and 1999, compared to 41.2%).

The car fleet being held mainly by households (about 95% of private cars [3]), its evolution depends principally on the evolution of the major determinants of households’ car ownership behaviours.

Figure 1 : Household car ownership by zone of residence



Sources : *Household Conjuncture Survey* (Insee) and, from 1995 on, *Parc Auto* panel survey (Sofrès).

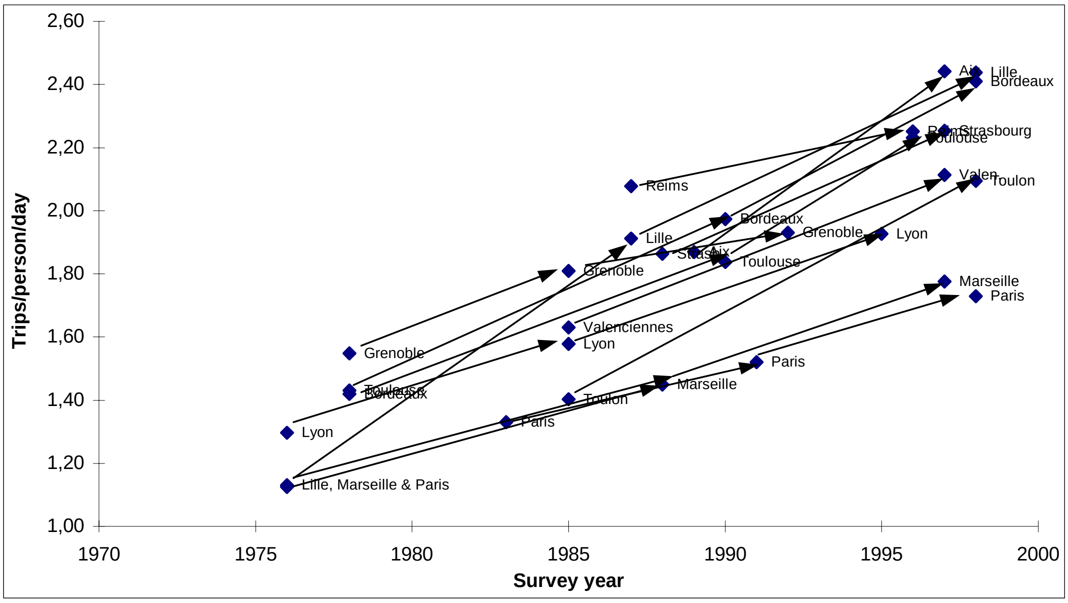
In particular, automobile ownership is strongly structured by the place of residence, because of differences between dense urban centres and peripheral or rural zones in terms of the availability of public transport means and of the acuteness of congestion problems. As a matter of fact, the proportion of motorised households increases as one moves away from the city-centre (Figure 1). The gaps widen over time because of the development of multi-equipment [4], more rapid in the suburbs and the periphery than in the centre (where the percentage of households having at their disposal two or more vehicles does not exceed 20% during the 1990’s).

2.2 Car Traffic

During the same period, the total traffic due to cars and light utility vehicles increased faster than the corresponding fleets: a growth of 40.9% (462 billion vehicle-km in 1999 against 328 in 1985) [5] whereas the fleet grew by only 32.4%.

Besides the mechanical effect of the increase in the number of vehicles, there are those of the “dieselisation” of the fleet and of changes in individual mobility behaviours. Indeed, even if it has slightly decreased during the last years, the mean annual mileage of a diesel vehicle is by far greater than that of a petrol vehicle (a difference of about 8,000 km). On the other hand, the use of the car in trips has continued to increase.

Figure 2 : Trips by private car – French urban areas

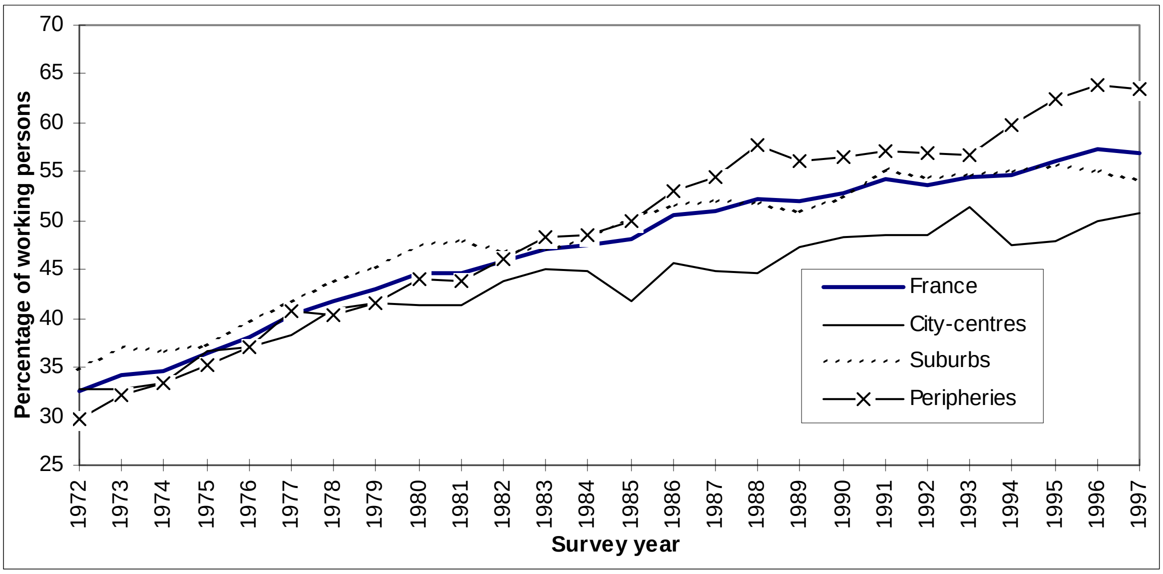


Sources : Household *Travel* surveys, CERTU-CETE Nord-Picardie.

Thus, the number of trips per person per day made by private car increased in all of the urban areas covered by household *Travel* surveys (Figure 2). The patterns observed from the national *Transport* surveys between 1981-82 and 1993-94 confirm the growing predominance of the automobile in individual mobility: the share of the private car in the mechanised local trips (during a week) increased by 8 percentage points to reach 84% (Madre *et al.*, 1997).

Like car ownership, car use differs according to place of residence. Indeed, the proportion of working persons going to work by car is greater in the peripheries than in the suburbs and in the city centres (Figure 3).

Figure 3 : Journey to work by car



Sources : *Household Conjuncture Survey* (Insee) and, from 1995 on, *Parc Auto* panel survey (Sofrès).

2.3 Urban Sprawl

The results of the 1999 census in France confirm the tendency to urban sprawl (Chavouet *et al.*, 2000) : between 1990 (previous census) and 1999, the urban population knew a 5.5% growth, attributable for almost the half to the absorption of new municipalities (677 new communes are classified as urban whereas 20 become rural again). However, even if the classic scheme of urban sprawl (i.e., a growth rate increasing as we go away from the centre) remains dominant, it has been attenuated : only 199 urban areas followed it between 1990 and 1999 while they were 231 to do so between 1982 and 1990 (Bessy-Pietri, 2000). Two other forms of urban development are in action : for some areas, population growth is greater in city-centres than in inner suburbs ; on the contrary, for others, among the most dynamic ones, it is greater in inner suburbs compared to city-centres or outer suburbs. Among the 73 areas with more than 100,000 inhabitants, 42 followed the first process, 17 the second, and 12 the third.

Globally, there appears to be a break relatively to the previous period: the suburbs, particularly the most densely urbanised ones, lose of their attractive power (the migratory balance was negative between 1990 and 1999 whereas it was positive between 1982 and 1990) while the migratory deficit of city-centres diminished. The natural growth makes the whole of city-centres have a slightly accelerated population growth and the suburban communes still have a growth rate greater than the national mean. The suburban rings hold positive natural and migratory balances.

As to rural areas, they knew a demographic renewal due to a migration contribution greater than the natural deficit in most of the municipalities. However, the distribution of this gain was not uniform. In general, the growth was strong in zones near dynamic urban areas ; on the contrary, the evolution was most often negative when “the urban structure *[was]* loose” (Bessy-Pietri *et al.*, 2000).

3. AN AGE-COHORT PERIOD MODEL

3.1 Why a Demographic Approach to Car Use ?

The profound structural changes which have accompanied the rapid growth of individual mobility in developed countries underline the necessity of studying transportation demand not in a context of equilibrium, but in a context of historical evolution (Goodwin *et al.*, 1987). Most of profiles of car ownership and individual mobility along the life cycle show changes over time, under the combined influence of the replacement of generations and of factors linked to the general economic environment such as the evolution of standards of living, of consumers’ tastes, and of supply.

The longitudinal approach highlights the complex impact of age which, in a dated temporal context, consists of the combination of three linked dimensions:

- the *moment in the life cycle*, which indicates the importance of age in car use behaviour;
- the *generation* (or *cohort*), which identifies the behaviour of individuals born during the same period, and therefore sharing a common life experience; and
- the *period*, which indicates the impact of the global socio-economic context.

3.2 Model Formulation

This approach requires survey data describing an element of the household’s (or individual’s) behaviour (here annual car mileage) and allowing different generations (or cohorts) to be followed over a long enough period (at least 10 years, and preferably 15 or 20 years). They can be obtained from a panel, or more often from a series of independent cross-sections (Deaton, 1985).

Let us denote M(a, g, t) a measure of this behaviour for households whose heads are a years old at date t and belong to the generation g defined by their birth year. Obviously, there is an exact relationship between these parameters:

$$g = t - a \qquad (1)$$

Let:

$$\mathrm{M}(a, g, t) = \alpha_a \mathrm{A}(a) + \alpha_g \mathrm{G}(g) + \beta_t \mathrm{T}(t) \qquad (2)$$

where A(a) and G(g) are respectively dummy variables for age a and generation g, and where T(t) denotes period effects which we will account for by introducing economic variables (income or total expenditure, and real prices).

This results in the following model :

$$M(a, g, t) = \alpha_a A(a) + \alpha_g G(g) + \beta \ln(CONS(t)) + \gamma \ln(PRICE(t)) \qquad (3)$$

where CONS(t) is household final consumption for all households (accounting for general economic growth) and PETPRICE(t) is a weighted price of fuels.

Due to equation (1), exact multicollinearity makes it impossible to estimate the coefficients of the model unless restrictions are imposed. Even if we estimate without intercept, dummy variables cannot cover all age groups and all generations. Thus, the age variables cover the life cycle, whereas the generation variables characterise all cohorts except one, which acts as a « reference generation » (here households whose heads were born between 1946 and 1955) and against which differences are estimated. Similarly, and for ease of interpretation, the variables representing period effects have to be set to 0 at the same date (here in 1994). Thus, each generation coefficient α_g can be interpreted as a gap between the cohort g and the « reference generation ». Moreover, the set of age coefficients can be interpreted as the car use curve along the life cycle for the « reference generation ».

4. ANALYSIS OF HOUSEHOLD CAR USE BY ZONE OF RESIDENCE

4.1 Definition of the Geographic Zones Considered

The urban areas defined by INSEE at the 1982 population census [6] constitute the basis of our geographic zoning. We distinguish four categories according to population size:

- the Paris area,
- urban areas with more than 300,000 inhabitants in the provinces,
- those with 50,000 to 300,000 inhabitants, and
- those with less than 50,000 inhabitants.

In each category, we distinguish the following concentric zones:

- the city-centre (the most populated commune in the area),
- the suburbs (the remainder of its agglomeration),
- the small and medium cities situated in the periphery, and
- the rural periphery.

Given the small sample sizes in the surveys used, defining a less fine zoning is necessary for model estimation. The « small and medium cities situated in the periphery » and the « rural periphery » are grouped to constitute the periphery of the area. By crossing the first three area sizes with the three types of zones thus obtained, we form 9 zones. A tenth zone is formed by the urban areas with less than 50,000 inhabitants and by rural municipalities outside urban areas.

4.2 A Comparative Analysis of Household Car Mileage by Zone

Pseudo-panels were constructed using data from the INSEE *Household Conjuncture Survey* ; the cohorts were formed according to the birth year of household head (or reference person). The data cover the period 1977-94, with about 10,000 households each year. The “short panel” structure of the survey (households are interviewed twice at one-year intervals in October) allows improving the precision of time-series calculated from individual data (Desabie, 1966 ; Cochrane, 1977). As children leave their parents’ home at different ages, depending on the social group and on the period, age and generation coefficients for young heads of households do not represent a full cohort. For this reason, households with heads under 20 were discarded before estimation. Households with heads aged 90 years or over were also excluded, because of too small samples.

Age effects are estimated through dummies of five-year age groups. The generation effects are estimated through dummies of ten-year birth periods. All of the cohorts born before 1916 were grouped. Two economic variables accounted for the effect of the period: households’ final consumption and a weighted price of fuels.

The following graphs represent the mean annual mileage, as simulated by the model, according to age and for the different cohorts. The life cycle profiles for the reference generation (here 1946-55) are obtained by representing the estimated age coefficients. Adding each generation coefficient to the coefficient of a given age class (here 35-39 years), we obtain a representation of the gaps between generations at the same age (of course, at different points in time).

Age effects

Like car ownership, mileage per household increases as one moves from city-centres to the peripheries, whatever the age of the reference person. Likewise, it increases with age, reaches a maximum, and then decreases. However, these profiles are more “erratic” than those of car ownership, particularly in their ascending phase. Moreover, the (steady) declines at the end of life cycle are stronger : indeed, vehicle use diminishes at old age, especially because of the disappearance of motives related to work.

For each type of area, the increase and decrease (respectively, at the beginning and at the end of life cycle) of household mileage are less important in city-centres than in the suburbs and the peripheries.

The types of area differ principally in terms of average mileage level : at every stage in life cycle, the average mileage per household is lower in the Paris region than in the big urban areas in the provinces and in the small urban areas. The age profile in the predominantly rural zones is almost identical to the one which prevails in the peripheries of the small areas.

Figure 4: Annual mileage per household along the life cycle, by zone
Paris urban area

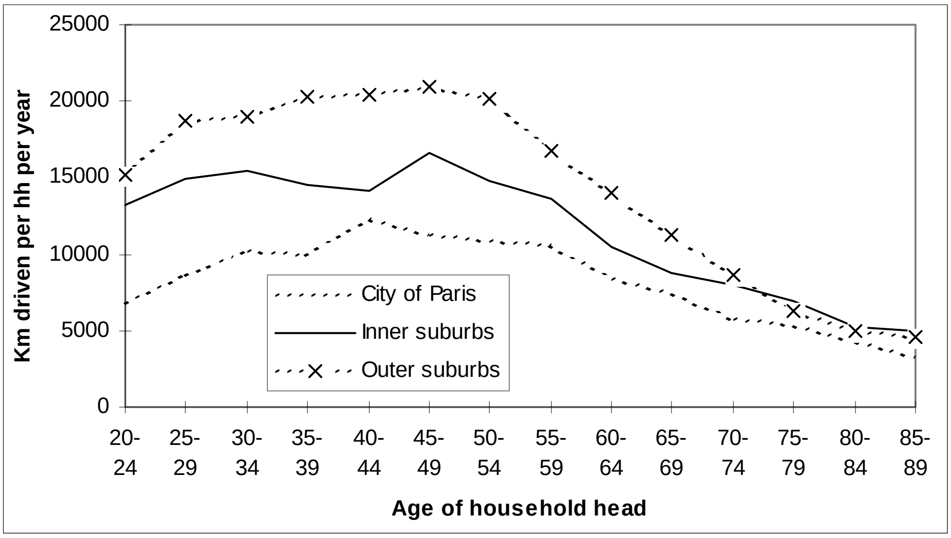


Figure 5: Annual mileage per household along the life cycle, by zone
Big urban areas in the provinces

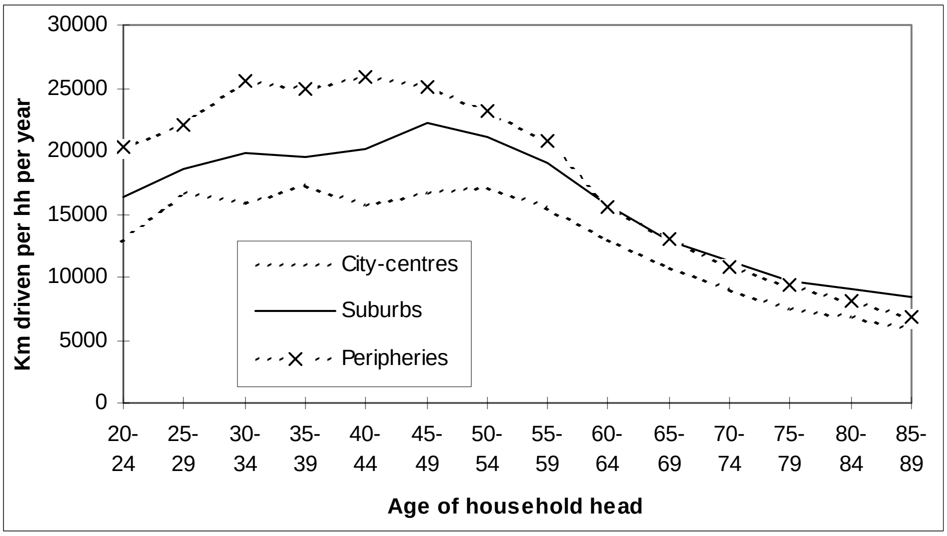
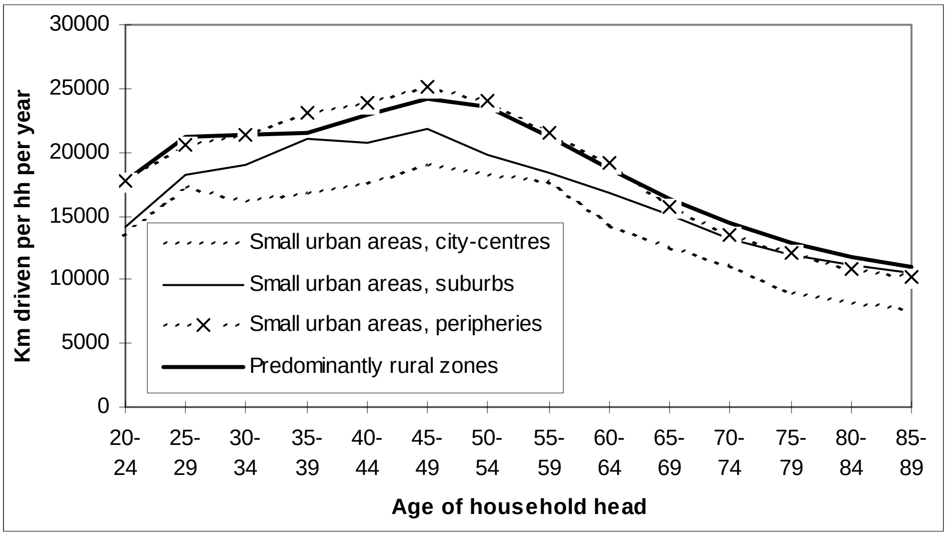


Figure 6: Annual mileage per household along the life cycle, by zone
Small urban areas and predominantly rural zones

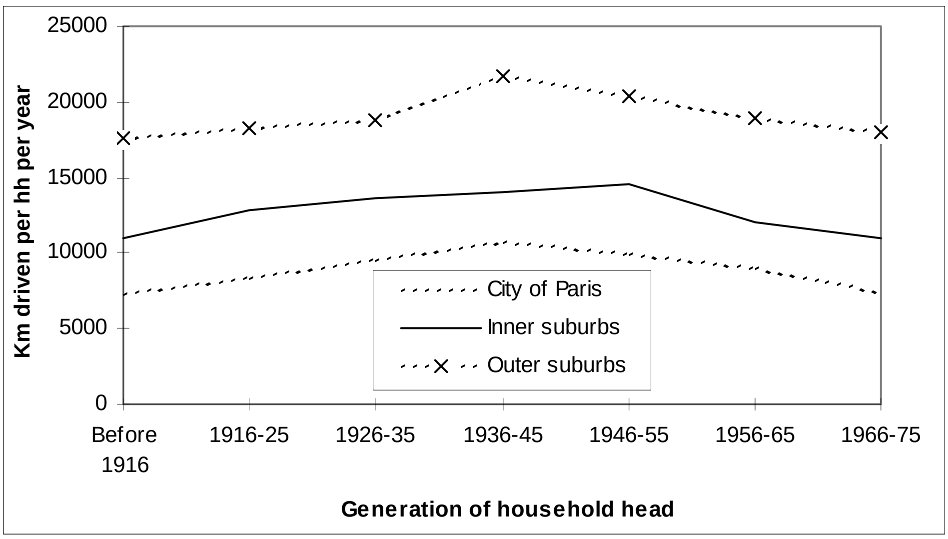


Generation effects

The following graphs show the average annual mileage per household for the successive generations at the age of 35-39, in each zone, as simulated by the model.

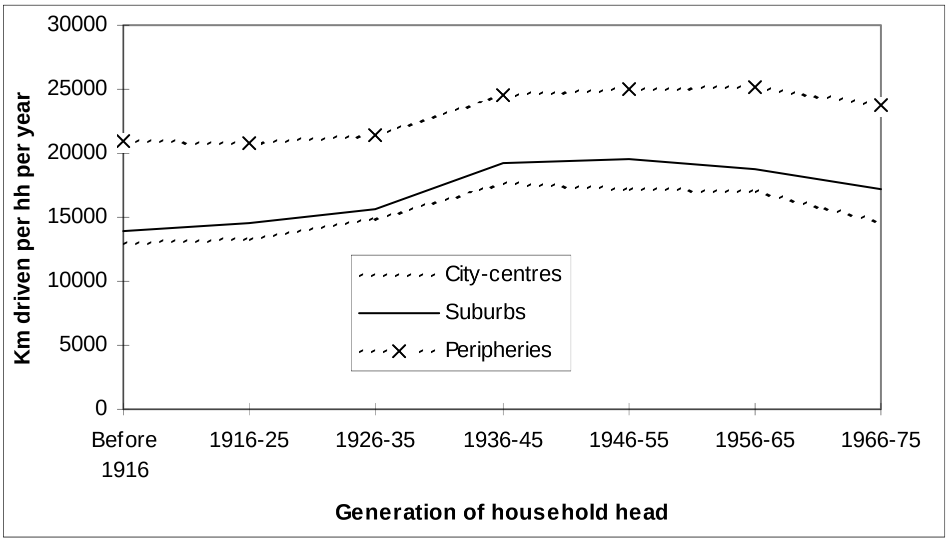
The Paris area is set apart by the existence of generations with maximum mileage : 1936-45 in the City of Paris and in the periphery, and 1946-55 in the inner suburbs of Paris. At the same age, the young generations make a relatively lesser use of the car.

Figure 7: Generation gaps at the age of 35-39, by zone
Paris urban area



In the big urban areas other than Paris, there is almost no difference between the generations born after 1936, except the younger cohort (1966-75) which sets slightly back.

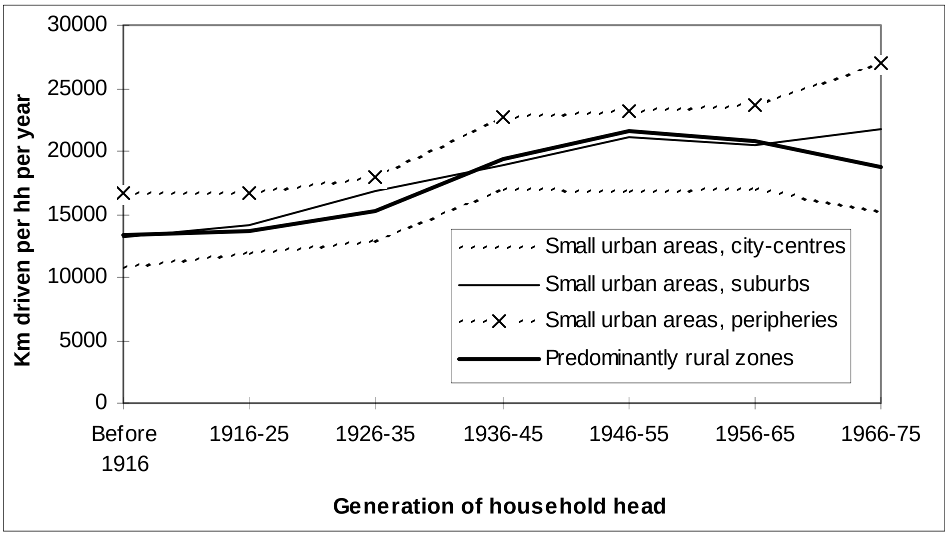
Figure 8: Generation gaps at the age of 35-39, by zone
Big urban areas in the provinces



City-centres of the small urban areas present the same configuration ; yet, in the suburbs and the peripheries the highest mileage is displayed by the youngest generations.

In the predominantly rural zones, the highest level of mileage is recorded by the generation born between 1946-55. However, the gaps relatively to this generation of the youngest cohorts are clearly less important than those of the older ones.

Figure 9: Generation gaps at the age of 35-39, by zone
Small urban areas and predominantly rural zones



Effects of economic growth and prices

The small sample sizes in almost all the zones makes it difficult to estimate the period effects. However, as for automobile equipment, we find differences in behaviour according to the zone of residence when we consider car use. They reflect differences between zones regarding the availability of alternatives to the car. The elasticities with respect to households' final consumption become more important as we move from city-centres to the peripheries, whatever the size of the urban area. Thus, the future of urban sprawl is likely to have consequences as to the possibility of a decoupling of traffic and economic growth (Madre *et al.*, 2002). As to the elasticities with respect to fuel prices, they are globally little different and particularly of low precision (Table 1).

Table 1: Effects of economic variables on household mean mileage, by zone

Dependent variable : kilometres driven per household per year.
Elasticities in 1993-95.

	Adj. R^2	Households' Final Consumption			Fuel Prices (FF/litre)		
		Coeff.	Std-Error	Elasticity	Coeff.	Std-Error	Elasticity
Paris urban area							
City of Paris	0.695	-	-	-	-	-	-
Inner Suburbs	0.905	3320.7	1725.5	0.30 [< 0.61]	-	-	-
Periphery	0.925	7171.3	2086.6	0.40 [0.17 ; 0.63]	-	-	-
Big urban areas (300,000+ inhabitants) in the provinces							
City-centres	0.937	4473.3	1820.0	0.36 [0.07 ; 0.65]	-1723.2	1342.6	-0.14 [> -0.35]
Suburbs	0.946	8286.4	2042.2	0.50 [0.26 ; 0.75]	-2101.7	1481.1	-0.13 [> -0.30]
Peripheries	0.863	12951.0	4320.7	0.65 [0.23 ; 1.08]	-2755.0	3139.5	-0.14 [> -0.45]
Small urban areas (50,000 to 300,000 inhabitants)							
City-centres	0.900	4803.7	2540.3	0.33 [< 0.67]	-2010.5	1869.9	-0.14 [> -0.39]
Suburbs	0.906	9304.2	2617.1	0.57 [0.26 ; 0.89]	-835.4	1894.5	-0.05 [> -0.28]
Peripheries	0.922	1423.0	2785.3	0.74 [0.45 ; 1.02]	-1260.0	2045.9	-0.07 [> -0.27]
Predominantly rural zones							
Rural	0.977	10687.0	1270.7	0.67 [0.51 ; 0.82]	-1772.9	944.2	-0.11 [-0.23 ; 0[
France	**0.989**	**8458.2**	**821.4**	**0.55 [0.44 ; 0.65]**	**-1418.0**	**605.0**	**-0.09 [-0.17 ; -0.02]**

Source : Estimations on data from INSEE's *Household Conjuncture Surveys* (1977-94).

Notes :

(1) Besides households' final consumption and a weighted price of fuels (in logarithms), the model accounts for generation of birth and age through dummy variables.

(2) Period variables are not accounted for in the case of the City of Paris. For Paris inner suburbs and periphery, only households' final consumption has been maintained in the regressions.

(3) As implied by the model specification, the elasticities are obtained by dividing the estimated coefficient by the annual household mileage in a given period (here, a mean over the years 1993-95). Confidence intervals are given between square brackets. Only one bound of an interval is mentioned if the other bound has the wrong sign (given the precision of the estimates).

5. PROJECTIONS OF HOUSEHOLD CAR TRAFFIC

In what follows, we present the projections of household car traffic (number of kilometres driven) by means of the demographic method. Relying on the estimated effects of age, of birth generation and of economic factors, life cycle profiles of household car mileage are projected for the successive cohorts in each of the 10 zones, according to six scenarios of evolution of the economic variables considered (three hypotheses on the annual growth of households' final consumption combined with two hypotheses on the annual growth of the average price of fuels [7]). The generation gaps estimated for the last observed cohort (1966-75) are maintained for the cohorts following it. In the projections, only households whose reference person is aged 20 to 89 years are accounted for. The cohort profiles are then combined with projections of the number of households by age group of the reference person according to three scenarios of urban sprawl to obtain the projected volumes of car traffic generated by households of each zone.

The scenarios of urban sprawl are defined on the basis of the observed migratory behaviours since the 1982 population census and in light of the developments in the urban sprawl process outlined above. Thus, we consider a high scenario extending the tendency to urban sprawl observed from 1982 to 1999, an intermediate scenario accounting for the inflexion observed between the censuses of 1990 and 1999, and a low scenario assuming no migration after the 1999 census (thus, assuming a stop in the urban sprawl process in 1999). The demographic projections are provided by the Omphale model of INSEE, based on the 1999 census results.

5.1 Projections According to Three Scenarios of Urban Sprawl

The tables below show the projections in billions of kilometres driven (total for metropolitan France and by size of urban area), according to the three scenarios of urban sprawl and a central scenario re the evolution of the economic variables (an annual growth rate of 2.3% for household consumption and of 0.49% for fuel prices, starting from 1994 [8]). Let us note that for the City of Paris only the demographic effects are taken into account in the projections, period effects being not statistically significant. As to its inner suburbs and its periphery, the period effects are present through household consumption alone [9]. Also note that in the backward projections for 1990, the scenarios of urban sprawl are not differentiated [10]. Relative differences between the highest and the lowest projections are measured in log differences, as suggested by Törnqvist *et al.* (1985). One desirable property of this measure is its symmetry, i.e. its magnitude does not depend on the point of comparison used. The log percentage differences ($100\times log_e(y/x)$, denoted by L%) are given in absolute value.

The projections give rise to contrasted patterns across zones. In general, and whatever the conurbation size, car traffic generated by households living in city-centres should be larger in the scenario of no migration after 1999, i.e. if urban sprawl were to stop at its observed situation at the 1999 census. The lowest figures are recorded by the High scenario (1982-99 tendency). This is in conformity with the revival of the attractive power of most of city-centres between the last two censuses. On the contrary, that generated by households living in the suburbs or in the peripheries would be greater if the sprawl process were to extend the tendency observed between 1982 and 1999 (High scenario). Then come in a decreasing order the Medium scenario (1990-99 tendency) and the Low scenario (no migration). The case of inner suburbs of Paris and of the big urban areas in the provinces is characterised by the Medium scenario giving rise to the lowest car traffic volume, which is in accordance with the loss of attractive power by these zones during 1990-99 compared to 1982-90, as noted above.

By conurbation type, the smaller the size of the area the greater the growth of traffic volumes between 1990 and 2020. In terms of volume of traffic, it is the Low scenario that dominates in the case of Paris region, whereas the Medium scenario leads in large urban areas in the provinces and the High scenario in small urban areas. The High and Medium scenarios give rise to very close volumes, particularly in the case of areas other than Paris. The relative gaps between the highest and the lowest figures are more important in the case of Paris region (about 8L% in 2020, compared to 3.5L% in the case of urban areas in the provinces, small or large).

Table 2 : Projections according to 3 scenarios of urban sprawl♠
Paris urban area

Unit : Billion

	Scenarios of urban sprawl			Relative differences* (|L%|)
	High (1982-99 tendency)	Medium (1990-99 tendency)	Low (No migration)	
1990	46.8	46.8	46.8	
2000	52.5	52.4	52.8	0.8
2005	55.2	54.8	56.7	3.4
2010	57.5	56.6	59.8	5.5
2015	59.9	58.3	62.5	7.0
2020	62.2	60.0	64.8	7.7
2020/1990 (%)	33.0	28.3	38.5	
2020/2000 (%)	18.4	14.4	22.7	

♠ And an annual growth of 2.3% for households' consumption.
* Relative differences between the highest and the lowest volumes projected.

Table 3 : Projections according to 3 scenarios of urban sprawl♠
Big urban areas in the provinces

Unit : Billion

	Scenarios of urban sprawl			Relative differences* (|L%|)
	High (1982-99 tendency)	Medium (1990-99 tendency)	Low (No migration)	
1990	87.6	87.6	87.6	
2000	113.2	113.2	113.2	0.0
2005	125.7	125.9	125.2	0.6
2010	137.4	138.1	136.0	1.5
2015	148.7	149.7	146.0	2.5
2020	159.4	160.5	155.0	3.5
2020/1990 (%)	81.9	83.2	76.9	
2020/2000 (%)	40.8	41.8	36.9	

♠ And an annual growth of 2.3% for households' consumption and of 0.49% for fuel prices.
* Relative differences between the highest and the lowest volumes projected.

Table 4 : Projections according to 3 scenarios of urban sprawl♠
Small urban areas

Unit : Billion

	Scenarios of urban sprawl			Relative Differences* (|L%|)
	High (1982-99 tendency)	Medium (1990-99 tendency)	Low (No migration)	
1990	64.0	64.0	64.0	
2000	87.2	87.2	87.1	0.2
2005	98.8	99.0	97.5	1.3
2010	110.5	110.7	108.2	2.2
2015	121.5	121.5	118.1	2.8
2020	131.8	131.5	127.3	3.5
2020/1990 (%)	106.0	105.5	98.9	
2020/2000 (%)	51.2	50.8	46.2	

♠ And an annual growth of 2.3% for households' consumption and of 0.49% for fuel prices.
* Relatives difference between the highest and the lowest volumes projected.

As to the predominantly rural zones, it is the Medium scenario that dominates, the lowest volumes being recorded by the no migration scenario. The relative difference between the two is greater than those shown by the different types of urban area (about 9L% in 2020). This result is in line with the demographic renewal (unevenly distributed between zones) observed in the rural areas between the last two censuses.

Table 5 : Projections according to 3 scenarios of urban sprawl♠
Predominantly rural zones

Unit : Billion

	Scenarios of urban sprawl			Relative differences* (|L%|)
	High (1982-99 tendency)	Medium (1990-99 tendency)	Low (No migration)	
1990	94.2	94.2	94.2	
2000	127.9	128.1	127.3	0.6
2005	143.8	144.5	139.7	3.4
2010	159.9	160.9	152.3	5.5
2015	174.5	175.9	163.6	7.2
2020	187.7	189.6	173.6	8.8
2020/1990 (%)	99.2	101.3	84.3	
2020/2000 (%)	46.7	48.1	36.4	

♠ And an annual growth of 2.3% for households' consumption and of 0.49% for fuel prices.
* Relatives difference between the highest and the lowest volumes projected.

The resulting traffic volumes at the national level (a sum over the 10 zones) show the predominance of the Medium scenario (extending the average migration behaviours of 1990-99), but it is very close to the High scenario. It gives rise to a 85% increase of car traffic between 1990 and 2020, whereas this would be of only 78% in the case of the Low scenario (no migration after the 1999 census). Its relative difference with the Low scenario increases with time, as at the zone level, but culminates at 4 log percentage points in 2020. The five-year growth rates become smaller the farther the horizon of projection.

Table 6 : Projections according to 3 scenarios of urban sprawl♠
France (sum over the 10 zones)

Unit : Billion

	Scenarios of urban sprawl			Relative differences* (|L%|)
	High (1982-99 tendency)	Medium (1990-99 tendency)	Low (No migration)	
1990	292.6	292.6	292.6	
2000	380.9	380.9	380.4	0.1
2005	423.4	424.1	419.1	1.2
2010	465.4	466.4	456.3	2.2
2015	504.5	505.4	490.1	3.1
2020	541.1	541.7	520.7	4.0
2020/1990 (%)	84.9	85.1	78.0	
2020/2000 (%)	42.1	42.2	36.9	

♠ And an annual growth of 2.3% for households' consumption and of 0.49% for fuel prices.
* Relative differences between the highest and the lowest volumes projected.

5.2 Projections According to Six Scenarios of Evolution of the Economic Variables

The impact of the two economic variables considered on the projected car traffic generated by households is evaluated by combining hypotheses of annual growth (from 1994 on) of these variables: three for household's final consumption (1.9%, 2.3% and 2.6%) and two for the weighted price of fuels (0.49% and 1.05%). Throughout, the High scenario of urban sprawl was maintained.

Table 7 : Projections according to 6 economic scenarios♠
France (sum over the 10 zones)

Unit : Billion

Annual rate of change (%)		2000	2005	2010	2015	2020	2020/2000 (%)
Hh. final Consumption	Fuel prices						
1.9	0.49	376.4	414.8	452.1	486.5	518.1	37.7
1.9	1.05	375.2	412.6	448.8	482.0	512.3	36.5
2.3	0.49	380.9	423.4	465.4	504.5	541.1	42.1
2.3	1.05	379.7	421.2	462.0	500.0	535.3	41.0
2.6	0.49	384.2	429.9	475.3	517.9	558.2	45.3
2.6	1.05	383.1	427.7	471.9	513.4	552.4	44.2
Relative differences* (|L%|)	Hh. final consumption	2.1	3.6	5.0	6.3	7.5	
	Fuel prices	0.3	0.5	0.7	0.9	1.1	

♠ Along with the High scenario of urban sprawl.
* Relative differences between extreme hypotheses.

The projections are more sensitive to variations in households' consumption than to changes in fuel prices. Indeed, the relative differences between the extreme hypotheses, which become wider the farther the horizon of projection, are at the national level of the order of 8% and 1%, respectively, in 2020.

By conurbation size, the smaller differences between scenarios of consumption growth are recorded by the area of Paris and the larger by the predominantly rural zones ; the large conurbations other than Paris and the small ones display similar differences of intermediate magnitude. As to the differences between hypotheses regarding the growth of fuel prices, they are small and vary little with conurbation size.

Table 8 : Projections according to 3 economic scenarios♠
Paris urban area

Unit : Billion

Annual rate of change (%)	2000	2005	2010	2015	2020	2020/2000 (%)
Hh. final consumption						
1.9	52.2	54.6	56.6	58.6	60.5	15.9
2.3	52.5	55.2	57.5	59.9	62.2	18.4
2.6	52.8	55.7	58.3	60.9	63.4	20.3
Relative differences* (|L%|)	1.1	2.0	2.9	3.8	4.7	

♠ Along with the High scenario of urban sprawl.
* Relative differences between extreme hypotheses.

Table 9 : Projections according to 6 economic scenarios♠
Big urban areas in the provinces

Unit : Billion

Annual rate of change (%)		2000	2005	2010	2015	2020	2020/2000 (%)
Hh. final consumption	Fuel prices						
1.9	0.49	111.9	123.2	133.5	143.4	152.6	36.3
1.9	1.05	111.4	122.3	132.1	141.4	150.1	34.7
2.3	0.49	113.2	125.7	137.4	148.7	159.4	40.8
2.3	1.05	112.7	124.7	135.9	146.7	156.8	39.1
2.6	0.49	114.2	127.5	140.2	152.6	164.4	44.0
2.6	1.05	113.7	126.6	138.8	150.6	161.9	42.4
Relative differences* (|L%|)	Hh. final Consumption	2.0	3.5	4.9	6.2	7.5	
	Fuel prices	0.4	0.8	1.1	1.3	1.6	

♠ Along with the High scenario of urban sprawl.
* Relative differences between extreme hypotheses.

Table 10 : Projections according to 6 economic scenarios♠
Small urban areas

Unit : Billion

Annual rate of change (%)		2000	2005	2010	2015	2020	2020/2000 (%)
Hh. final consumption	Fuel prices						
1.9	0.49	86.1	96.7	107.3	117.1	126.2	46.5
1.9	1.05	85.9	96.2	106.6	116.1	125.0	45.6
2.3	0.49	87.2	98.8	110.5	121.5	131.8	51.2
2.3	1.05	87.0	98.3	109.8	120.5	130.7	50.2
2.6	0.49	88.0	100.3	112.9	124.8	136.1	54.6
2.6	1.05	87.8	99.9	112.2	123.8	134.9	53.7
Relative differences* (|L%|)	Hh. final consumption	2.2	3.7	5.1	6.4	7.5	
	Fuel prices	0.3	0.5	0.6	0.8	0.9	

♠ Along with the High scenario of urban sprawl.
* Relative differences between extreme hypotheses.

Table 11 : Projections according to 6 economic scenarios♠
Predominantly rural zones

Unit : Billion

Annual rate of change (%)		2000	2005	2010	2015	2020	2020/2000 (%)
Hh. final consumption	Fuel prices						
1.9	0.49	126.1	140.3	154.7	167.5	178.8	41.8
1.9	1.05	125.7	139.5	153.5	165.8	176.7	40.6
2.3	0.49	127.9	143.8	159.9	174.5	187.7	46.7
2.3	1.05	127.5	143.0	158.7	172.9	185.6	45.6
2.6	0.49	129.3	146.3	163.8	179.7	194.3	50.3
2.6	1.05	128.9	145.5	162.6	178.1	192.2	49.2
Relative differences* (|L%|)	Hh. final consumption	2.5	4.2	5.7	7.1	8.3	
	Fuel prices	0.3	0.6	0.8	0.9	1.1	

♠ Along with the High scenario of urban sprawl.
* Relative differences between extreme hypotheses.

6. CONCLUSION

The analysis of household mileage by zone of residence evidenced differences in behaviour according to conurbation size and distance to centre, through the impacts of demographic factors (age and generation) as well as those of economic factors (household consumption and fuel prices). Thus, accounting for the future development of urban sprawl and for modifications in the population of households, both in level and in structure, is necessary for the long term projection of car traffic.

Inspection of the respective influences of urban sprawl and of economic growth on the projected volumes raises some remarks about the scenarios envisaged. Indeed, although the choice of growth scenarios is arbitrary, the scenarios of urban sprawl seem more contrasted. Yet, the relative gaps in 2020 are greater according to the economic variants than to those of sprawl. Thus, at the national level these differences are of the order of 8L% and 4L% respectively, though the situation differs according to urban area type [11]. To some extent, this may be due to the formulation of the hypotheses adopted.

On the one hand, supposing a constant growth rate of total consumption whereas the number of households should increase less and less rapidly [12] implies an acceleration of the growth of consumption per household.

On the other hand, given the data available, the scenarios of urban sprawl were defined according to a fixed zoning based on the urban areas (ZPIU) defined at the 1982 census. As a result, they have limits as to the apprehension of the evolution of the phenomenon of urban sprawl over a long period. Indeed, a spatial distribution according to a *constant geography* results in an increase or a decrease of the number of households in the *same space*. Even if this should not cause major distortions in the case of city-centres, it can be the case for certain suburbs and peripheries. In fact, influence areas widen for most of urban poles, but they can shrink for others ; likewise, some poles may “appear” and others “disappear” [13]. Hence, it seems more appropriate to adopt an *evolutionary geography* (Julien, 2000).

Notes

[1] French National Institute of Statistics and Economic Studies.
[2] Figures regarding the automobile fleet come from various issues of *L’Industrie Automobile en France*, a publication of the Committee of the French Car-makers (CCFA).
[3] Estimations by CCFA. See CCFA (1998a), p. 20.
[4] The proportion of bi-motorised households passed from 21% in 1985 to 25% in 1999 ; that of tri-motorised households from 2.5% in 1985 to 4% in 1999 ; and that of mono-motorised households stabilised around 51%. See CCFA, *op. cit.*
[5] Source : CCFA, based on *Les comptes des transports (Transportation accounts)*, Insee-DAEI/SES.
[6] Zones de Peuplement Industriel ou Urbain (ZPIU).
[7] In accordance with the hypotheses adopted by the French Ministry of Transport for the projection of transport demand to 2020 (METL-SES, 1998).
[8] The last observation year for the survey data used.
[9] See the table above summarising the effects of economic variables.
[10] The scenarios of urban sprawl are differentiated only for the years 2000 and beyond.
[11] The relative differences for the scenarios of consumption growth and urban sprawl are similar in the case of the predominantly rural zones (8.3L% and 8.8L%, respectively), but this is not so in the case of the Paris region (4.7L% and 7.7L%, respectively), of large urban areas in the provinces and of small urban areas (7.5L% and 3.5L%, respectively).
[12] From the projections of Omphale model according to the central scenario (referred to as the High scenario of urban sprawl in this paper), the growth rate of the number of households in (metropolitan) France should be of 4.5% between 2000 and 2005, 4.1% between 2005 and 2010, 3.3% between 2010 and 2015 and of 2.8% between 2015 and 2020.
[13] Julien (2000) makes an inventory of “appearances” and “disappearances” of poles between 1982 and 1990 and between 1990 and 1999 (p. 12).

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