CAR OWNERSHIP MODELLING IN THE ILE DE FRANCE REGION

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1. INTRODUCTION

In several urban areas in Europe the long-term trend of increasing car ownership per household has changed into a phase of stabilization or even decline. Meanwhile, in rural areas, the increase of car ownership rates seems to continue. This regional discrepancy can clearly be observed in the Île-de-France region, which consists of the city of Paris, the urban area formed by its closest suburbs (Petit Couronne - PC) and a both urbanized and rural area at larger distance (Grand Couronne- GC). Over the last two decades, these three areas have shown a very different pattern in car ownership development varying from declining car ownership rates for households in urban Paris to increasing car ownership rates in the outer region.

Île-de-France Mobilités, the mobility and transport authority for Paris region, uses the ANTONIN model, a large-scale disaggregate transport model, to forecast travel demand in the Île-de-France region. It is used to evaluate public transport projects and to prepare the Île-de-France sustainable urban mobility plan (PDUIF). In this context, future forecasts for car ownership of households are very important, as it determines to a large extent mode and destination choices made by the household. It is therefore necessary that the car ownership module can address these diverse regional trends correctly.

For the current ANTONIN 3 model, the car ownership module is a cross-sectional model and was estimated on the Global Transport Survey 2010 (EGT 2010). In this module, the probability for a household to own one or several cars depends on household and zonal characteristics, such as average income. The cross-sectional estimated influence on income is also applied as the influence of income over time. Therefore, the model is well capable of addressing zonal differences in existing car ownership but does not reproduce correctly the differences in trends between the different types of area in Île-de-France. In particular, developments in car ownership rates in the city of Paris are overestimated as increasing incomes are estimated to be a main driver from EGT 2010 observations.

The challenge for this study is therefore to develop a car ownership module which is in line with the observed trends, while ensuring that this module remains well integrated with the rest of the ANTONIN model. To take up this challenge, we follow a new approach:

- In the model estimation: integration of longitudinal evolutions in addition to cross sectional differences;
- In explanatory variables: inclusion of urban developments and policies negatively affecting the competitive position of the car.

This means that static disaggregate car ownership models by themselves would no longer be sufficient to produce reliable forecasts: a combination with aggregated time series models or pseudo-panel/cohort models is needed to address the regional trends. For the Île-de-France region we estimated pseudo-panel models, based on the EGT travel surveys conducted between 1976 and 2010 (or parts of it), which are then applied in combination with a cross-sectional model estimated on the EGT 2010 data.

In this paper, we will present and discuss our estimation results and apply the new car ownership module to perform:

- An internal validation for the estimation period 1976-2010,
- and a forecast, for 2010-2025, in order to check how plausible forecasts are with the new module for the different areas of the Ile-de-France region.

2. CAR OWNERSHIP DEVELOPMENTS IN ILE-DE-FRANCE

The historic trend of increasing car ownership per household has changed for parts of Île-de-France over the last decades. In the city of Paris, car ownership per household has been declining at an increasing rate since 1990. In the PC, car ownership rates per household have been mainly stable over the 1990s but have started to decline afterwards. These trends in the more urban parts of Île-de-France are in contrast with the growth of car ownership rates in the period up to 2010 observed in the GC.

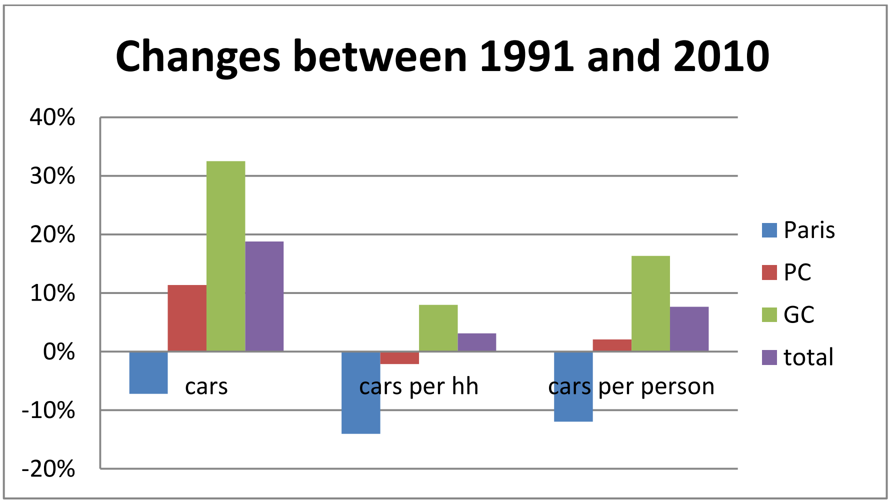

Figure 1: Changes in number of cars and car ownership by zone (Source : EGT 1991 up to 2010)

Between 2010 et 2015, the population census databases show that the number of cars per household keeps decreasing in Paris (- 9 %) and PC (- 2 %), while in GC it remains stable. The number of cars drops 10 % in Paris, is up 1 % in PC and 5 % in GC.

Those kinds of evolution are not specific to Île-de-France: the literature shows that similar findings of declining or stagnating car ownership levels are observed in other urban regions. For example, car access levels by households in London have decreased slightly in the period 2005-2012 (TfL, 2012). Other sources for the whole of the UK indicate a long-term growth pattern in cars per households for the period 1971-2006 (RAC foundation,2008). Another example of contrasted trends in urban areas compared to other regions can be found in Amsterdam where the growth in car ownership per capita, in the period 1994 – 2008, is only half the growth in car ownership per capita at the national level (De Groote et al., 2016).

Those similarities with what is observed in Île-de-France makes it worthwhile to consider the factors that explain such trends in other regions. Traditional car ownership research focusses on personal and household characteristics such as income, gender, employment, age and license holding. The generation effect, strongly presented in cohort models, seems to diminish over time as car license holding differences between age groups are becoming smaller (de Jong et al, 2008). However, it might be relevant again to address the impact of changing attitudes of young people toward license holding. Regarding the relationship between income and car ownership, the effect of saturation levels for higher income groups seems to be relevant to include. This factor, possibly in combination with other factors, results in lower income elasticities for car ownership as indicated by TfL 2012 and Goodwin 2012. For the case of Île-de-France, this trend is also mentioned in the work of Cornut 2016.

The differences in car ownership rates by household between urban and non-urban areas is well observed and addressed in the literature. Car ownership research has demonstrated that people in urban areas are less car dependent, typically have more competitive alternatives, and therefore are more sensitive to changes in conditions for car ownership and in levels of service of other modes (Dargay, 2002). In practice, this difference between urban and rural areas is often included by using an urban dummy in the analysis addressing the different conditions. This approach is sufficient to address the differences between regions for a specific year, but insufficient if the trend in car ownership differs between urban and rural areas.

The change in car ownership trends in urban areas like Paris, from increasing towards decreasing number of cars per household, seem to be related to specific urban developments in this period. The changes in car ownership trends for urban areas seem to follow the changes in urban strategies and policies. The two decades leading up to the mid-1990s were marked for most cities by a pro-car agenda consisting of urban road investments, relaxed parking policies, suburbanization and modest public transport investments. Over the last two decades however, urban policies have radically shifted towards a limitation of the use of private cars by both push factors (like reallocating road space and parking capacity to other purposes or pricing policies) and pull factors (like large scale public transport investments and prioritising active modes).

The ITDP (2011) report indicates that the Paris city administration has taken a much firmer stand on the use of private cars in public spaces and on-street parking supply was reduced by 9% in the period 2003-2007. Furthermore, in the same period, 95% of the free spots were turned into paid parking spaces. Some of the parking spots were removed to accommodate alternative modes of transport, like Velib stations (bike share service). Road capacity for private cars was also reduced to create additional space for public transport or active modes. As a consequence, the average car speed in the city of Paris has reduced by almost 25% over the last two decades (1996-2016, Observatoire des déplacements à Paris). According to other sources, congestion on the expressways, more relevant for residents in the PC and GC, has remained moderately constant within the same period (Lesteven, 2014).

The main lesson of this analysis is that to improve car ownership modelling in Île-de France, the following issues must be addressed:

- Integrate longitudinal developments in addition to cross-sectional differences: for example, the changing relationship between income and car ownership model should be analysed by using time series data including income and car ownership developments;
- Account for zonal factors affecting the competitive position of the car: local differences in factors like parking availability and costs, road capacity, or PT services, play an important role in explaining car ownership levels. Differences in policies between urban areas and other areas, affecting these factors, makes it important to address longitudinal developments.

3. CAR OWNERSHIP MODELLING METHODOLOGY

This section discusses the various options to model car ownership and proposes a preferred option to integrate in the ANTONIN model of Île-de-France Mobilités. A review by de Jong et al. (2004) distinguishes the following model types for car ownership (a more recent review by Anowar et al. 2014, uses more or less the same typology):

1. Models on aggregate data:
    a. Aggregate time series models
    b. Aggregate cohort models
    c. Aggregate car market models
    d. Heuristic simulation models
2. Models on disaggregate data:
    a. Static disaggregate car ownership models
    b. Joint discrete-continuous models of car ownership and use
    c. Static disaggregate car type choice models
    d. Panel models
    e. Pseudo-panel models
    f. Dynamic car transaction models

The current car ownership models in ANTONIN belong to category 2a (static disaggregate car ownership models). These models can include the influence of income and other socio-economic variables that will change over time. But for forecasting, one has to assume that the behavioural coefficients that are estimated on variation in the socio-economic variables between households at one point in time can be applied for changes in these socio-economic variables (such as income) over time. Given the observed decline in motorisation found for inner Paris and the stabilisation in the PC, while differences in socio-economic trends are small, maintaining this assumption for the car ownership model seems questionable. To study these differences in trends, a more dynamic approach for car ownership should be added to the model.

Approaches that qualify as dynamic are: 1a (aggregate time series models), 1b (cohort models), some of the models in 1c (aggregate car market models), 2d (panel models), 2e (pseudo-panel models) and 2f (dynamic transaction models). These approaches are briefly discussed below.
Many of the dynamic approaches to car ownership assume some form of saturation in motorisation. However, until recently, the experience was that in due time all assumed motorisation thresholds were surpassed. This led some researchers to abandon the concept of a threshold on the number of cars owned per household or even per adult (thereby assuming that there could even be more cars than adults, with different cars for specific purposes owned by the same person). However, the data for Paris and other large cities in developed countries now show signs that a saturation in motorisation might have been reached in specific metropolitan areas.

Aggregate time series models have limited data requirements (the required data are only the number of cars, possibly per household or adult, per zone and per year, and aggregated explanatory variables that also vary between the zones and/or the years). Such data are available for Île-de-France. These models are not well suited for the inclusion of all sorts of socio-economic explanatory factors, but average income per zone and year might be included.

Cohort models will be discussed under pseudo-panel models, since the year of birth (in classes) has been a part of all pseudo-panel models for car ownership that we know of. A cohort model can be based on data on car ownership by birth year that becomes available to the researcher in aggregated form (e.g. from registration data) or by building a pseudo-panel from repeated cross-sectional surveys.

Aggregated car market models can be static or dynamic. Developing an aggregated dynamic car market model for Île-de-France (with distinctions between many vehicle types, new and second-hand purchases, endogenous car prices and technological and economic scrappage) would go far beyond the scope of a car ownership model for ANTONIN, so this is not investigated further in this proposal.

Panel models require panel data for a longer period (preferably several decades) and for several points in time (at least three, preferably four or more). The Parc Auto survey, carried out by Kantar Sofres, has some panel nature (most respondents are included in at least two waves), but cannot meet the above requirements.

Dynamic transaction models (including models for car ownership duration until replacement or moving to a situation with a different number of cars in the household) also require panel data or retrospective data on car ownership. As far as we know, this kind of data is not available for Île-de-France either.

Panel or pseudo panel data have the advantage that temporal evolutions can be distinguished from cross-sectional differences. In a real panel data, individual respondents are followed over time; unfortunately for this study, no such data are available. As an alternative to real panel data, pseudo-panel data can be used. A pseudo-panel consists of segments of respondents (called cohorts) that are followed over time. They can be formed by combining similar cross-sectional datasets (such as the EGT) from different years. It is important for the quality of the models to include as many waves as possible, at least three, better more, and to cover several decades, in order to get sufficient variations over time.

In conclusion, static disaggregated car ownership models appear to be no longer sufficient on their own for reliable forecasting. The proposed alternative for ANTONIN is to combine a dynamic model with static disaggregated car ownership models in order to provide an allocation of cars over the various types of households. Pseudo-panel models and time series models are the two possible options for the dynamic model considering the datasets available. Pseudo-panel models allow to include multiple socio-economic explanatory variables coming from the same database as the dependent variable (a repeated cross-sectional survey). Conversely, in time series analysis, the data comes from various sources and may not be very consistent. We therefore prefer pseudo-panel methods over aggregated time series models, especially if these are to be combined with static disaggregated models estimated on the same original cross-sectional surveys.

4. DATA AND ESTIMATION RESULTS

In the pseudo-panel approach, two sets of data are needed: household level data from EGTs for the years 1976, 1983, 1991, 2001 and 2010 and time series data to take account of the regional trends.

Regarding households**,** the following data were extracted from the EGTs: number of cars, department of residence, gross yearly household income (ten classes), number of children, number of adults, car driver licences (license for reference person), gender and year of birth of the reference person.

Various time series attributes have been tested in the model estimation to account for 'regional' trends. Some time series are available for each of the three zones (Paris, Petite Couronne and Grand Couronne) and all the available EGT years and some only for some zones or years. The following explanatory time series variables were derived and tested:

- PT availability: index of the number of seat.kilometers in the zone (2001 = 100), not available for 1976;
- Roads: index of the major road surface in the zone (2001 = 100), not available for 1976;
- Parking: index of the parking surface in the zone (2001 = 100)
- Fuel cost: A time series for fuel expenses by households is available, but this does not include the EGT years 1976 and 1983.
- New car cost: The average purchasing cost of new cars.

Both fuel cost and new car cost are global variables, without differentiation between zones or cohorts.

In the estimation data, the characteristics of the individual EGT household records are aggregated to group averages. Besides the cohorts and the EGT year, we thereby also distinguish between the three Île-de-France zones. The resulting estimation dataset has therefore the following dimensions:

- Cohort: Gender of the head of the household in combination with the year of birth of the head of the household (in 5-year classes);
- Zone: Zone in which the household is living: Paris, Petite Couronne, Grande Couronne;
- EGT year: Year of the EGT for the observations: 1976, 1983, 1991, 2001 and 2010.

The variables in the estimation data are the average number of cars per household as dependent variable and all explanatory variables that are detailed in this section.

Regarding the model estimation process, we have followed a stepwise approach with the following steps:

1) Base model including household characteristics and zonal dummies;
2) Final model including explanatory variables for zonal trends (PT availability, roads, car cost) and different income coefficients by zone.

Figure 2 and 3 show that, although the base model has a reasonably good fit, it is not capable of addressing the change in trend from car ownership growth towards car ownership decline in inner Paris.

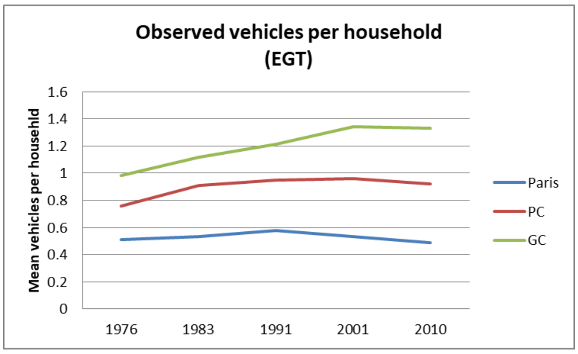

Figure 2: observed car ownership (source EGT)

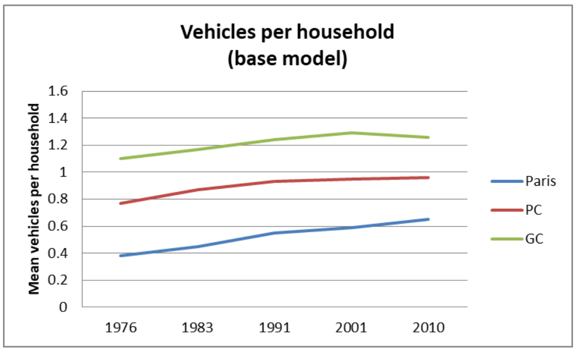

Figure 3: modelled car ownership (base model)

The final model (figure 5) is much better than the base model. It can address the changes in trends by including explanatory zonal variables influencing the attractiveness of owning a car. Those zonal variables appear crucials (in addition to household characteristics) to be able to explain and forecast regional developments in car ownership.

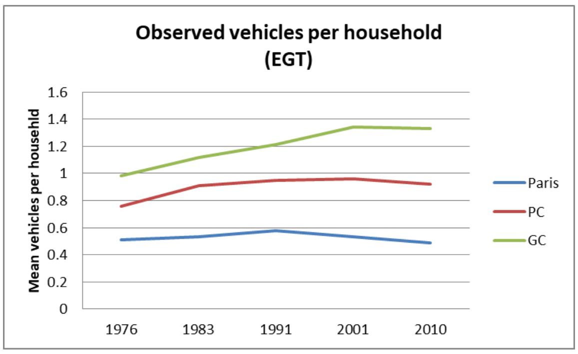

Figure 4: observed car ownership (source EGT)

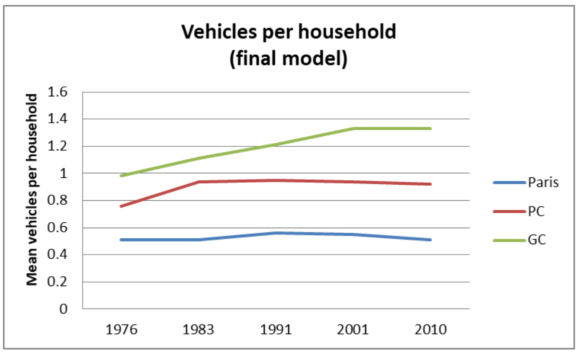

Figure 5: modelled car ownership (final model)

The estimation results for the final model are presented in table 1. The final model includes different income coefficients for each of the three zones, which leads to plausible income elasticities of 0.4 for Paris and the PC and 0.37 for the GC. As a result of the inclusion of zone-specific coefficients the zonal constants have swapped sign and need to be interpreted in combination with the zonal income variable and coefficient. The goodness of fit of this model is 0.978 (adjusted r^2).

Table 1: Coefficient estimates of final car ownership model

	Coefficient	Std. Error	t	Sig.
Overall constant	-2.864	.401	-7.145	.000
Disposable income (logarithm) Paris	.201	.038	5.339	.000
Disposable income (logarithm) PC	.397	.041	9.613	.000
Disposable income (logarithm) GC	.527	.038	13.948	.000
Number of adults	.344	.034	10.129	.000
Number of children	.072	.017	4.173	.000
Petite Couronne	-1.729	.289	-5.974	.000
Grande Couronne	-2.787	.280	-9.957	.000
Age under 25	-.061	.034	-1.796	.073
Age 25 – 35	-.027	.018	-1.526	.128
Age 45 – 55	.087	.020	4.424	.000
Age 55 – 65	.178	.029	6.066	.000
Age 65 and over	.222	.041	5.454	.000
Cohort <1905 M	-.631	.082	-7.698	.000
Cohort <1905 F	-.448	.083	-5.367	.000
Cohort 1905 - 1909 M	-.529	.081	-6.541	.000
Cohort 1905 - 1909 F	-.499	.080	-6.214	.000
Cohort 1910 - 1914 M	-.444	.072	-6.187	.000
Cohort 1910 - 1914 F	-.502	.075	-6.711	.000
Cohort 1915 - 1919 M	-.407	.072	-5.622	.000
Cohort 1915 - 1919 F	-.500	.075	-6.715	.000
Cohort 1920 - 1924 M	-.292	.062	-4.688	.000
Cohort 1920 - 1924 F	-.443	.066	-6.677	.000
Cohort 1925 - 1929 M	-.275	.060	-4.602	.000
Cohort 1925 - 1929 F	-.352	.063	-5.543	.000
Cohort 1930 - 1934 M	-.188	.055	-3.440	.001
Cohort 1930 - 1934 F	-.290	.060	-4.829	.000
Cohort 1935 - 1939 M	-.140	.051	-2.750	.006
Cohort 1935 - 1939 F	-.238	.058	-4.119	.000
Cohort 1940 - 1944 M	-.097	.048	-2.029	.043
Cohort 1940 - 1944 F	-.154	.054	-2.845	.005
Cohort 1945 - 1949 M	-.051	.042	-1.215	.225
Cohort 1945 - 1949 F	-.137	.048	-2.870	.004
Cohort 1950 - 1954 M	-.025	.040	-.621	.535
Cohort 1950 - 1954 F	-.127	.046	-2.774	.006
Cohort 1955 - 1959 M	-.006	.034	-.183	.855
Cohort 1955 - 1959 F	-.120	.042	-2.887	.004
Cohort 1960 - 1964 M	-.009	.034	-.277	.782
Cohort 1960 - 1964 F	-.077	.042	-1.815	.070
Cohort 1965 - 1969 M	.025	.031	.824	.410
Cohort 1965 - 1969 F	-.043	.039	-1.101	.272
Cohort 1970 - 1974 M	-.006	.030	-.189	.850
Cohort 1970 - 1974 F	-.038	.045	-.844	.399
Cohort 1975 - 1979 M	.005	.031	.150	.881
Cohort 1975 - 1979 F	-.019	.044	-.438	.661
Cohort 1980 - 1994 F	.023	.045	.496	.620
PT availability	-.557	.084	-6.657	.000
Roads	1.394	.115	12.118	.000
1976 correction Paris	-.310	.053	-5.847	.000
1976 correction GC	-.110	.019	-5.772	.000
1976 correction PC	-.075	.019	-3.950	.000

For the internal validation, presented in Table 2, the forecasts of the final model (see figure 5) are compared with car ownership by household extracted from the EGTs survey data (see figure 2). Overall, the model is well capable of reproducing the historical EGT data.

Table 2: Internal validation comparison of model and EGT results for car ownership per household by zone and year

	Paris		**PC**		**GC**	
	EGT	Model	EGT	Model	EGT	Model
1976	0.51	0.51	0.76	0.76	0.98	0.98
1983	0.53	0.52	0.91	0.93	1.12	1.12
1991	0.58	0.58	0.95	0.94	1.21	1.22
2001	0.53	0.54	0.96	0.93	1.34	1.32
2010	0.49	0.48	0.92	0.93	1.33	1.34

Remarks:
Several additional aspects were tested or evaluated but did not make it to the final model. These are:

- Parking: The index of parking surface in the region (2001 = 100) was tested as an explanatory variable in the model. Its coefficient was not significant and therefore not included in the final model;
- Fuel cost: A time series for fuel expenses by households is available, but this does not include the EGT years 1976 and 1983. Two years absence of data seems too much for a good estimation of the fuel cost effect, also because this concerns a global variable (i.e. without differentiation between the three zones or cohorts). Besides, the study by Cornut (2016) did not find a significant result for fuel cost on car ownership based on largely the same data. Therefore, we have not included this factor;
- New car cost This variable was tested but became insignificant in the final model and during the estimation the sign of the coefficient was instable;
- Weighting: The estimated models are weighted regression models, with the number of underlying households per data point as the weighing factor. An unweighted regression model was also tested, but this gave a lower goodness of fit and its validation results were not as good as for the weighted regression model.

5. APPLYING THE REGIONAL CAR OWNERSHIP MODEL

Applying the car ownership model means that we must make scenario assumptions for the variables in the model. For demographic and socio-economic variables, we can use the socio-economic data available in the zonal data for 2025 already used in ANTONIN. Additional to this scenario assumptions need to be made on the developments in factors such as public transport and road availability in the three Île-de-France zones.

For illustration purposes we have derived and used the following sets of scenario settings for 2025 applications of the pseudo-panel model:

- Scenario 1: *no road or public transport developments* and for 2025 the 2010 values for these variables are used

- Scenario 2: *trend developments for road area and PT availability* for the period 2000-2010 are extrapolated towards 2025. This means an increase in PT availability of 20% in Paris, 17% in PC and 14% in GC in 2025 compared to 2010. For the road area this means a 4% decline in Paris and a 3% increase in PC and 7% increase in the GC.
- Scenario 3: *trend developments PT availability all zones and road in Paris combined with more restrictive, no growth in road area, for the PC and GC.* This means an increase in PT availability of 20% in Paris, 17% in PC and 14% in GC in 2025 compared to 2010. For the road area this means a 4% decline in Paris and no change in PC and GC
- Scenario 4: *first interpretation of existing plans for Road and PT (not a formal scenario).* This means an increase in PT availability of 15% in Paris, 40% in PC and 30% in GC. For the road area this means a 2% decline in Paris and no change in PC and GC.

The effect of using these scenarios on the estimated number of cars per household for each of the three zones is illustrated in table 3 and figure 6 below. For reason of comparison the 2010 figures and modelling results of the old car ownership model are also included.

Table 3: Car ownership by household results for various scenario runs

	Base year	**Old model**	**New pseudo-panel model**			
	2010	2025	Scenario 1 2025	Scenario 2 2025	Scenario 3 2025	Scenario 4 2025
Paris	0.49	0.56	0.60	0.39	0.39	0.47
PC	0.92	0.98	1.04	0.99	0.94	0.80
GC	1.33	1.39	1.44	1.45	1.35	1.26

The results of the old model and scenario 1 of the new model show an increase in car ownership for all zones resulting from socio-economic scenario developments including a rise in average incomes of 21% in Paris and 17% in PC and GC. In the new pseudo panel model the forecasted evolution in car ownership is also influenced by developments in road and PT availability within the zones. Scenario 2 shows that car ownership is declining by 20% for Paris in case of extrapolating the 2000-2010 developments in road area and PT availability. Extrapolating the trends under scenario 2 for the PC and GC results in a 7% and 9% increase in car ownership for these zones. Scenario 3 shows that in case of no further expansion of the road area the car ownership levels are almost constant for these two zones.

The fourth scenario, which gives a first interpretation of the existing plans up to 2025, shows a decline in car ownership per household for all three areas. For the Paris area this scenario means a more modest decline in car ownership than over the last two decades. The lack of road investments and ambitious PT investments for the PC and GC results in a steep decline of 13% in car ownership for the PC and a decline of 6% for the GC.

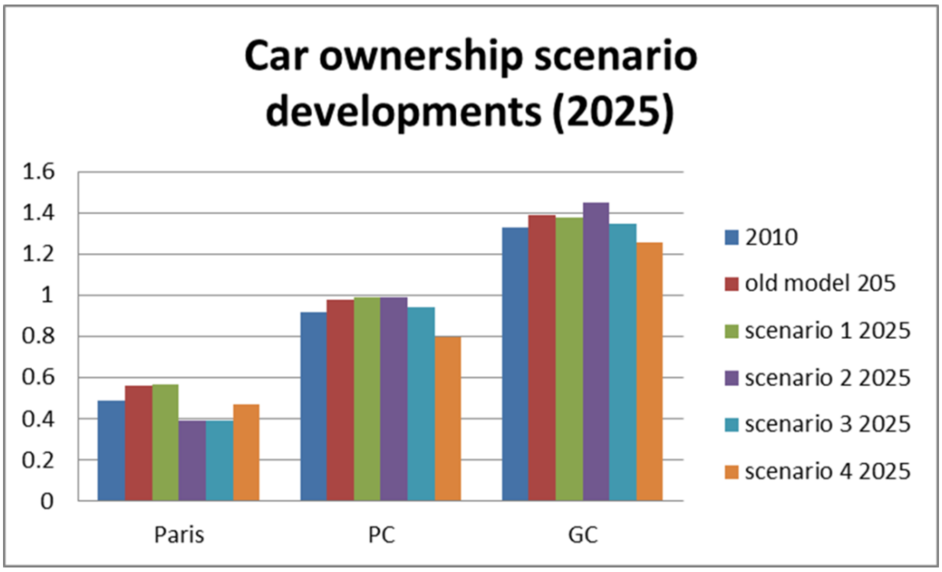

Figure 6: 2025 Car ownership per zone using various alternative scenario assumptions for the regional factors

6. CONCLUSIONS

The existing static disaggregated car ownership model currently used in ANTONIN 3 modelling is not capable to address the differences of trends in car ownership between Paris and less urbanized parts of the Ile-de- France region. In particular, it has difficulties to represent the decline in car ownership for inner Paris while household incomes in the same period have increased (e.g. the model calculates increase in car ownership when applied to 2001-2010 period). To solve this issue, we have addressed longitudinal evolutions, in addition to cross-sectional differences, by developing a dynamic pseudo-panel model to simulate household car ownership development for three regions within Ile-the-France. An advantage of the pseudo-panel model is that it has been estimated on single source time series EGT data and that it allows including multiple socio-economic explanatory variables besides more aggregated variables.

Furthermore in this research we have focussed on the explicit inclusion of regional factors affecting the competitive position of the car. The advantage of using these regional factors, instead of only working with regional dummies, is that they can address different regional developments like parking availability and costs, road capacity and levels of service of public transport, plus their evolution over time. This is especially relevant as growing differences in policies affecting these factors can be observed between urban areas and other areas.

The estimation results confirm the relevance of regional factors like road surface and public transport availability in explaining the different trends, besides household and personal factors such as income, age, gender, number of adults and children. Regarding the influence of household income on car ownership, there is a significant positive relationship in all three zones, with income elasticities between 0.3 and 0.4. Another aspect is that higher income household are less sensitive than lower income households: this is reflected by taking the logarithm of income. The cohort influence, related to the year of birth, is diminishing as the differences in car license holding become smaller between cohorts. Other factors such as parking space and car costs, like cost of a new car or fuel costs, are found to be insignificant and are therefore not included in the model.

Test applications of the model show that the model can produce plausible scenarios for the development in car ownership by household per region. Compared to the old version of the model, the new model can produce different trends by region depending on the scenario assumptions for the regional factors in the modelling. Depending on these scenario settings, a range of potential evolutions in future car ownership can be generated by region. The pseudo-panel model for Paris, PC and GC is fully integrated within the ANTONIN model. The new model sets the targets for the total number of cars in these three areas; they are then distributed at the level of transport zones, over 1 800 in ANTONIN, and household type with the existing cross sectional disaggregate car ownership models.

Overall it can be concluded that the pseudo-panel approach gives satisfactory results and that it is possible to estimate a plausible car ownership model with this approach. Challenging aspect was that all EGTs (in total 5), dating back to 1976, were needed to generate enough data points. This means that additional data, like regional factors, needed to be collected dating back to 1976. This severely limits the availability of data on ‘potential’ explanatory variables. The change in set up of the EGT surveys into an annual survey since 2018 is promising from this perspective: soon, more data points within a shorter time frame will be available to improve the analyses.

Applying ANTONIN including this regional car ownership model is more demanding in terms of scenario setting than the existing model. In addition to standard scenario assumptions on socio-economic aspects, the regional car ownership model also needs plausible assumptions on the changes in regional factors influencing car ownership, that depend on regional policies. In practice the model users of the ANTONIN model need to build up experience with defining these scenario assumptions.

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References

Anowar, S., N. Eluru and L.F. Miranda-Moreno (2014) Alternative modelling approaches used for examining automobile ownership : a comprehensive review, Transport Reviews, Vol. 34, No. 4, 441-473

Cornut (2016), ‘Longitudinal analysis of car ownership and car travel demand in the Paris region using a pseudo-panel data approach’, Transportation Research Procedia **13** (2016) 61-71

Dargay, J. (2002) Determinants of car ownership in rural and urban areas: a pseudo-panel analysis, Transportation Research Part E 38, 3513–66.

Goodwin, P. (2012) Peak travel, peak car and the future of mobility: Evidence, unresolved issues, policy implications, and a research agenda, OECD/ITF Roundtable on Long-run Trends in Travel Demand, Paris, France, Discussion Paper No. 13

Groote de J., J. van Ommeren and H. Koster (2016) Car ownership and residential subsidies: Evidence from Amsterdam, Economics of transportation journal 6, pp 25-37

ITDP(2011) Europe's Parking U-Turn: From Accommodation to Regulation, report prepared by Michael Kodransky and Gabrielle Hermann

Jong, G.C. de, J. Fox, A.J. Daly, M. Pieters and R. Smit (2004) Comparison of car ownership models, Transport Reviews, Vol. 24, No. 4, 379-408

Jong, G.C. de and O. van de Riet (2008) The driving factors of passenger transport, EJTIR, 8(3), 228-251

Lesteven G (2014) Behavioral responses to traffic congestion – findings from Paris, Sao Paulo and Mumbai, TRA Paris

Royal Automobile Club Foundation for Motoring (2008) Car ownership in Great Britain, report prepared by David Liebling

Transport for London, How many cars are there in London and who owns them, Roads task force – technical note 12