MEASURING UNCERTAINTY IN LONG-TERM TRAVEL DEMAND FORECASTING FROM DEMOGRAPHIC MODELLING

–Case Study of the Paris and Montreal Metropolitan Areas–

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Uncertainty on traffic forecasts may have an impact on reimbursement scheduling for investment, as well as for scenarios for operating costs. Even the best projections are based on models and assumptions, thus raising the question of their accuracy. Indeed, long term investments are risky and it is important to cope with uncertainty. This paper deals with the uncertainty on a long term projection with an Age-Cohort approach. We used the jackknife technique to estimate confidence intervals and observe that the demographic approach outlines the structural determinants for long term trends of mobility.

Key Words: Uncertainty, Variance, Jackknife, Projection, Age-cohort model, Paris, Montreal

1. INTRODUCTION

For transportation and infrastructure planning, traffic forecasts by mode are essential. A clear understanding of long term trends is important, and is a necessary step to elaborate scenarios and estimate relative costs (public vs. private transport). Uncertainty on traffic forecasts may have an impact on socioeconomic cost-benefit impact analysis, reimbursement scheduling for investment, as well as for scenarios for operating costs. Even the best projections are based on models and assumptions, thus raising the question of their accuracy. Indeed, long term investments are risky and it is important to cope with uncertainty.

Even though models based on demographic tendencies are probably those which resist best long term analysis[1,2], it remains crucial to take into account uncertainty in long term modelling and try to measure it in the form of a margin of error with confidence intervals. This paper will present such an approach based on long term travel demand forecasting with a demographic approach applied to the Paris and Montreal metropolitan regions. Three main sources of uncertainty or errors will be discussed: calibration of the model, behaviour of future generations, and demographic projections. One main source of error, the calibration of the model, will be illustrated with the Paris – Montreal comparison. The other two sources of error will be discussed with the Paris example.

2. PRESENTATION OF THE AGE-COHORT MODEL

2.1 The model

The model used is essentially based on an age-cohort approach taking into account the impact of the life-cycle and generation effects through time on travel behavior[3,4], which permits to outline the impact of age and generation combined with various structural variables: gender, spatial distribution, motorization of the households[5].

The "Age-Cohort" model can be treated as a model of analysis of variance with two main factors (age and generation):

$$\pi_{a,k} = \sum_{a \in A} \alpha_a I_a + \sum_{k \in K} \gamma_k I_k + \varepsilon_{a,k} \qquad (1)$$

Where:

$\pi_{a,k}$: measures a characteristic or behavior (daily kilometers, number of trips per day,…); "a" is the age band of the individual reflecting the life-cycle and "k" his generation, defined by his date of birth;

α_a : measures the behavior of a generation of reference at the age band "a". This allows us to calculate a « Standard Profile » of the life cycle;

I_a : are the dummy variables of the age band "a".

γ_k : measures the gap between the cohort "k" and the generation of reference γ_{k0};

I_k : are the dummy variables of the cohort "k".

$\varepsilon_{a,k}$: is the residual of the model (which includes all other factors).

The unit of measurement used is the standard five years cohort which is usual in demographic analysis. It was used both for the definition of the generations and for the description of the standard life profiles, with the exception of age groups with small samples which required to be aggregated (individuals aged 85 years and older were classified in the age group "85 and over", and the individuals born before 1907 were grouped with the generation group "1907-1911".

In order to be able to distinguish between life-cycle and generation effects, the calibration of an Age-Cohort model (based on the analysis of variance) requires data on the mobility behavior of individuals for at least two observation periods. With two observations, there is no residue. However, it is preferable to have more observations to obtain a residual term taking into account factors not included in the model (i.e. income or price effects). In the present case we chose two cities with more than three surveys; Paris (Paris metropolitan region, or Île-de-France, with 4 Global surveys, 1976-77, 1983-84, 1991-92, 1997-98) and Montreal (Montreal metropolitan region: with 6 origin-destination surveys: 1974, 1978, 1982, 1987, 1993, 1998). The sample size for the Global surveys in Paris are around 10 000 respondent households (except for 1998 with 3 500) and in the 50 000 to 60 000 range for Montreal. The model for each case study was calibrated with these household O-D surveys, which furnish detailed data on travel behavior on a typical weekday, and detailed demographic data by quinquennal age groups (observed and projected).

The following structural variables are explicitly taken into account:

age (with its components of life-cycle and generation) and gender;

spatial distribution for the zone of residence representing different density levels and distance to the centre of the urban area (Central City, Inner Suburbs and Outer Suburbs);

level of motorization of the households (0 car, 1 car, 2 cars or more). This criterion, a proxy for the individual access to automobile, proves quite discriminatory relative to the zone of residence and the distance travelled which increases with motorization.

We ran 18 models of analysis of variance crossing the following variables: three zones of residence, three level of motorization and two gender. Therefore, there is no a direct evaluation of the "goodness of fit" of the model on the overall population. The mobility is measured by two variables:

global mobility or frequency of trips (average number of trips per person for a typical week day)

distance travelled (number of kilometers travelled per person for a typical week day).

2.2 Mobility projections

The projection of mobility (daily kilometers, number of trips per day,…) for an individual of zone of residence z, level of motorization v and gender s at the date t is given by:

$$\pi_{a,k}^{z,v,s} = \alpha_a^{z,v,s} + \gamma_k^{z,v,s} \qquad (2)$$

Where:

t=a+k (a is the age of the individual reflecting the life-cycle and k is generation, defined by date of birth);

α_a : measures the behavior of a generation of reference at the age a. This allows us to calculate a « Standard Profile » of the life cycle;

γ_k : measures the gap between the cohort k and the generation of reference γ_{k0};

Since the gaps of the cohort of recent generations tends to disappear we took the last observed cohort gap for future generations[6].

The mobility for the population at the date t is estimated as follows:

$$M_t = \frac{\sum_{z=1}^{3}\sum_{v=0}^{2}\sum_{s=1}^{2}\left(P_{a,t}^{z,v,s} * \pi_{a,k=t-a}^{z,v,s}\right)}{\sum_{z=1}^{3}\sum_{v=0}^{2}\sum_{s=1}^{2} P_{a,t}^{z,v,s}} \qquad (3)$$

Where:

$P_{a,t}^{z,v,s}$ is the population projection of zone of residence z, level of motorization v and gender s at the date t.

2.3 A first measure of the adequacy of the model

To compare globally the observed results with the model, for both regions, and both models (trips and distance) we adjusted a regression between the observations of the surveys and the estimates of the model at the finest level, i.e. crossing of the variables:

zone of residence (3);