Using a demographic-based model in forecasting travel demand in Hanoi

Thanh Tu NGUYEN [a], Jean-Loup MADRE [b],

[a] *University of Transport and Communication, Hanoi, Vietnam*
E-mail:thanhtunguyen.utc@gmail.com
[b]*French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks (IFSTTAR),*
E-mail: jean-loup.madre@ifsttar.fr

Abstract: This paper aims at better understanding the impact of changing demographics on the long-term evolution of daily mobility, using a demographics-based model to estimate the distance traveled by each transportation mode, by zone of residence and gender.

Keywords: Daily mobility, Distance traveled, Long term forecasting, Demographic-based Model.

1. INTRODUCTION

Long-term travel demand forecasting is essential for urban transport planning. Household travel surveys are the most commonly used statistical surveys to analyze daily mobility in an urban area and are also widely used worldwide by planners to develop these projections (Krakutovski, 2004). However, these are cross-sectional surveys, meaning that they provide only a snapshot of mobility during one day of a single year. Because cross-sectional surveys are confined to a specific point in time, they have limitations for long term travel demand forecasting (Madre, 1989), (Gallez, 1994). Since travel behavior tends to change over time, efforts to predict future travel behavior based only on most recent cross-sectional surveys seems to be inappropriate. For instance and more recently (Grimal, 2011) have shown that long-term income elasticities with respect to transport behavior cannot be drawn from cross-sectional analysis, because cross-sectional elasticities are not constant over time. Long-term travel demand modeling, based on data collected at different points in time during a long enough period, seems to be the most appropriate way to take into account the impact of changes in travel behavior for long term forecasting (Kitamura, 1990). The main objective of this paper is to give some elements for a better understanding of the impact of changing demographics on the long-term evolution of daily mobility in Hanoi city using a demographic-based models to forecast mobility patterns such as: trip frequency, distance travelled, average trip distance.

2. LITERATURE REVIEWS

Demography is an important determinant of travel behavior. Indeed, the curve of distance traveled according to age is bell-shaped, with a maximum around 35-39 years (16,2km in 2005 and 18,1km traveled per day in 2012 in Hanoi). A straightforward combination of fixed mobility by age group with the evolving number of inhabitants suggests that the demographic transition (i.e. a slower growth of the number of inhabitants with population ageing) could lead to a peak in the total amount of car travel, which is occurring in developed countries since the 2000’s (Milard-Ball & Schipper, 2010; Kuhnimof et al., 2011).

The samples from different cross-sectional surveys change from one year to another, but it is possible to follow cohort of persons defined by their year of birth (Gallez, 2004), using a pseudo-panel approach which was first introduced by (Deaton, 1985). It is based on grouping individuals from cross sectional observations into cohorts, the averages of which are then treated as individual observations in a panel. These data can be used in the absence of "real" panel data to simulate the following up of virtual persons over long time periods and test for generation membership effects.
To evaluate these effects (age, generation and period) on transport behavior, and to make long-term projections of mobility, researchers of the French National Institute for Transport and Safety Research (INRETS)[1] developed a demographic approach for forecasting. The construction of this dynamic model for transport demand was made in the 80's mainly based on work developed by (Madre, 1989) (Madre et al.,1996) first for car ownership, then for mobility. They established that it was possible to use pseudo panel data sets to forecast travel demand with reliable results (Figure 1).

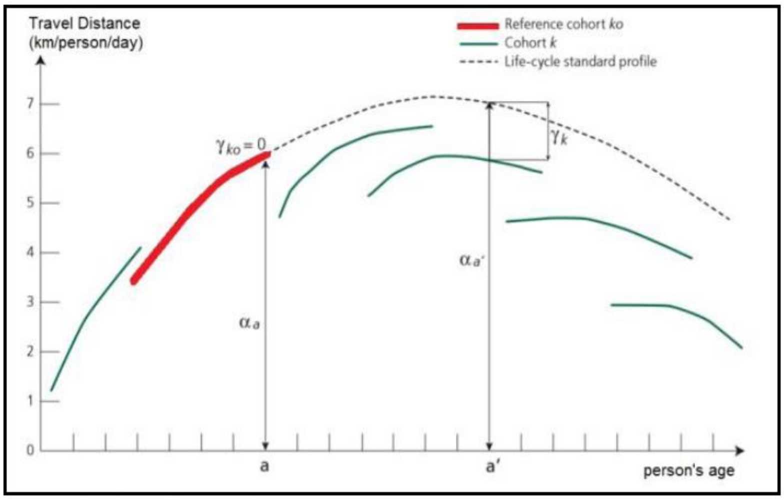


Figure 1: Life-cycle standard profile and travel activity
Source: based on (Gallez, 1994)

Another examples for this method in the transport planning field are Bush (2003), a study aiming to forecast future travel demand of older adults; Dargay (2002, 2007) and Huang (2007), where the substantial influence of cohort effects on household car ownership is modelled; (Krakutovski,2004) for travel demand forecasting in Lille, France; (Dejoux et al., 2010) in projection travel demand for ageing groups in Montreal and Paris. Developing countries began to use this forecasting approach for cities such as Sao Paulo, Brazil (Madre et al., 2000) and Puebla, Mexico (Bussière et al., 1996) and Ciudad Juares, Mexico (Tapia-Villarreal, 2014).

In most cases, the regression parameters applied on for different cities indicates that the Age-Cohort model estimates appropriately travel activity by the analysis criteria (e.g. gender, zone of residence, age, etc.). In relation to forecast precision, (Dejoux et al., 2010) have found that the demographic approach for long term forecasting with an Age-Cohort model applied to

[1] From 2011, The French National Institute for Transport and Safety Research **(**INRETS**)** and the French Central Laboratory of Roads and Bridges (**LCPC**) were merged to become The French institute of science and technology for transport, spatial planning, development and networks (in french: Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux, IFSTTAR)

Paris and Montreal, gives generally good results with errors in the 10-15% range. Errors can reach higher levels (in the range of 30-40%) mainly when the size of the sample is very small. In addition to age and cohort effects previously mentioned, and in an effort to take into account urban form and the dynamics of transport behavior, researchers have applied Age-Cohort model in order to forecast travel demand by zone (Tapia-Villarreal, 2014). In general, they have shown that travel distance declines with density and this trend seems to continue in the future in many cities of developed countries.

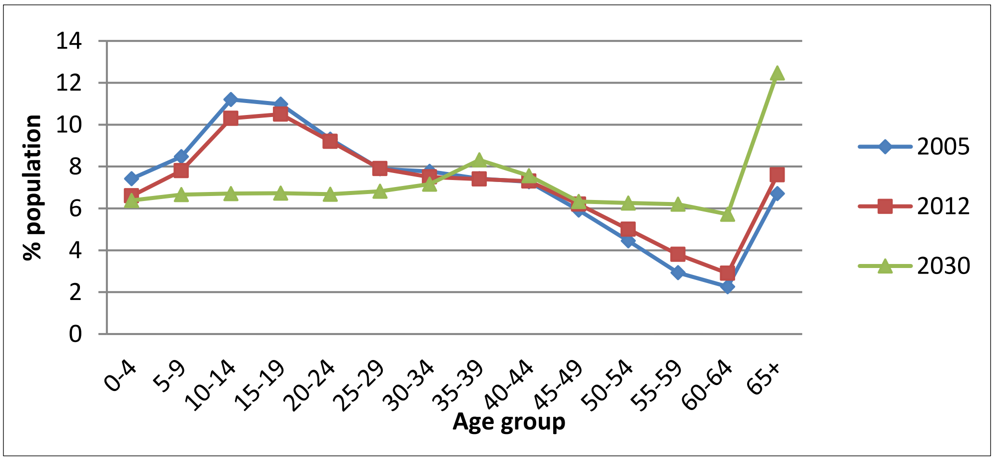
3. METHODOLOGY

3.1. Travel demand modeling

Ageing of the population, urban sprawl will change travel patterns. To illustrate this phenomenon, we applied a demographic-based projection model of travel behavior in the period of 2005–2030 in Hanoi for measuring various elements of daily mobility such as trip frequency, distance travelled, average trip distance. The model, based on the demographic trends in a longitudinal analysis, reveals the complex role of the age factor which, in a dated temporal context, consists of a combination of three inter-linked dimensions:

- The stage in the life cycle, which expresses the influence of age on travel behavior. By evaluating the effects of the stage in the life cycle, it is possible to obtain a characteristic curve for those changes which can be related to age (we shall refer to this as the standard life profile).
- The generation (or cohort), which takes into account travel behavior on the basis of membership of a group of individuals born during the same period, who therefore share a common ‘life experience’. Introducing this generation gap effect (which can be measured by means of differentials) allows us to place this profile in a long-term perspective.
- A complete Age-Cohort-Period model, which is not considered here, would take into account the period effect, which expresses the influence of the overall economic context on behavioral changes. In such a model, the period effect expresses the importance of socio-economic factors which affect all individuals and households simultaneously (e.g. changes in legislations, cost of fuel).

The Age-Cohort model supposes that age and generation behaviors shall be stable over time till the horizon of projection.



Graphic 1. Projection of population based on census.

Table 1. Demographic changes in Hanoi city (in thousand pers.)

Year	2005	2012	2030
Population	**5691**	**6719**	**9300**
Male	2806	3292	4538
Female	2885	3427	4762
Central city	1731	2118	1934
Inner suburbs	1434	1863	2815
Outer suburbs	2527	2737	4551
Average age	29.3	30.8	36.4

Source: Population projection based on census

3.2. Presentation of the age-cohort model

The description of the Age-Cohort Travel Demand Forecast Model is taken from (Dejoux et. al, 2010). 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, which permits to outline the impact of age and generation combined with various structural variables: gender, spatial distribution, motorization of the households …

We used a variance analysis model which is written as follows:

$$\pi_{a,k} = \sum_{a\epsilon A} \alpha_a I_a + \sum_{k\epsilon A} \gamma_k I_k + \varepsilon_{a,k}$$

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" over the life cycle;

I_a: are the dummy variable of the age band *a*.

γ_k: measures the gap between the cohort *k* and the generation of reference $\gamma_k 0$;

I_k: are the dummy variable 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 used in demographic analysis, with the exception of age groups with small samples which required to be aggregated (individuals aged 65 years and older were classified in the age group '65 and over' and the individuals born before 1940 were grouped with the generation group '1936-1940').

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. It is preferable to have three or more observations to obtain a residual term taking into account factors not included in the model (i.e. income or price effects). But in Hanoi, we only have 2 source of survey data with large sample size:

- First, the Household travel survey in 2012, in the study of transport master planning in Hanoi City until 2030, with a sample of 18000 households.
- Second from the JICA study in the Programme of the Comprehensive of Urban Development of Hanoi city in 2005 with the participation of 20.000 households.

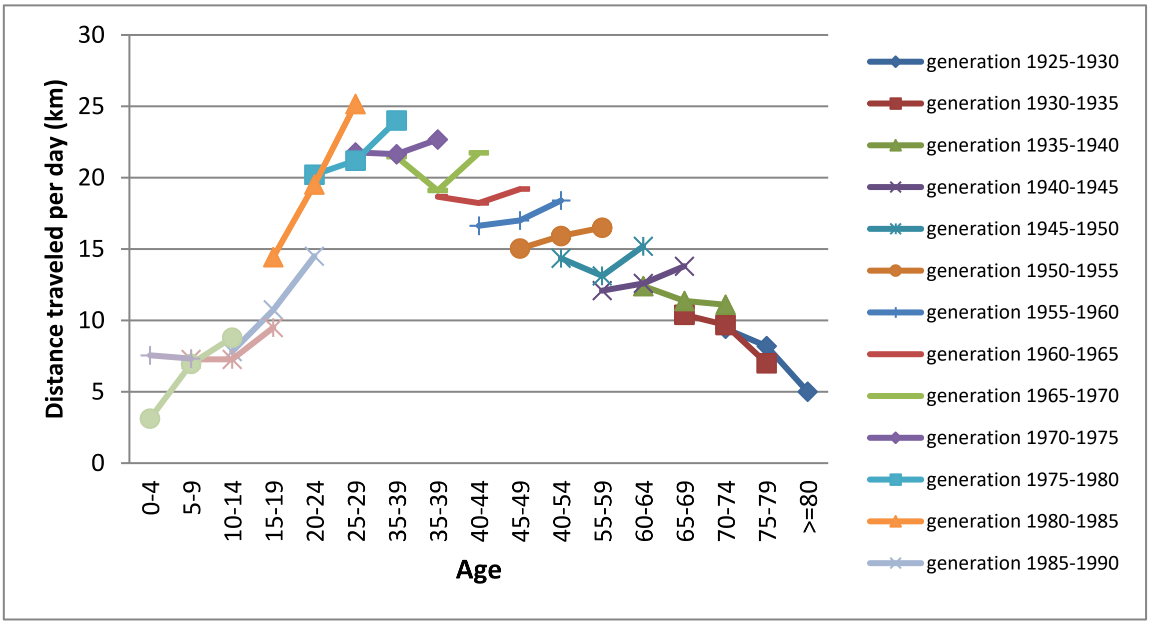
The following variables have been considered in the model's specification:

- Age (with its life cycle and generational components) and gender.

- Zone of residence: we have identified three concentric zones with diminishing density from the centre to the outer suburbs. The denser zone is the central city (in Hanoi, the population density is greater than 10.000 pers/km2), the inner suburbs show less density (from 2.000 to 10.000 pers/km2) and the outer suburbs with very low densities (the rest of the region) with approximately 1000 pers./km2.

At these two points in time (2005 and 2012), age and gender should have similar impacts on travel demand patterns which rise as we get farther from the centre. We have run 6 models of variance analysis by crossing the following variables: three zones of residence and two genders. Mobility is measured by two variables:

- Global mobility or frequency of trips (average number of trips per person for a typical week day);
- Distance traveled (number of kilometers travelled per person for a typical week day).



Graphic 2. Distance traveled per person for a typical weekday from 2005 and 2012 surveys

3.3. The model for projection of mobility

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

$$\pi_{a,k}^{z,s} = \alpha_a^{z,s} + \gamma_k^{z,s}$$

where:

t = a + k (a is the age 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 a. This allows us to calculate a 'Standard Profile' over the life cycle;

γk: measures the gap between the cohort k and the generation of reference $\gamma_k 0$; Since the gaps in cohorts for recent generations tend to disappear we took the last observed cohorts gap for future generation (Madre et al., 1995).

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

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

where:

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

3.4. Model fitting

As the model only provides five-year results, we had to estimate the results for the survey years by linear interpolation. To make a more comprehensive comparison between the observations and the results of the model, we calculated regressions among the observed values and the model's estimations at the most detailed level, i.e. by crossing the following variables:

- zone of residence (three zones);
- gender (2);
- five-year age groups (14);
- survey dates (2).

We had approximately 168 points for 2 surveys. To validate the model we need that:

- the R2 value be close to 1;
- the gradient be close to 1;
- the constant be not significantly different from 0.

The 'Age-Cohort' model seems well suited with travel demand forecasting as all the above conditions were met (see table 2) :

Table 2. Regression between the observed values and the age-cohort model estimations

Model	R^2	Gradient		Constant	
		Param. estimated	t-value	Param. estimated	t-value
Distance travelled	0.98	0.98	88.2	0	2.92
Trip rate	0.99	0.99	273.6	0	1.48

Source: Household travel surveys 2005 & 2012

The mean trip length was calculated by dividing the estimated daily distance traveled by the trip rate.

4.RESULTS

4.1. Travel demand forecasting

Firstly, we estimated the average number of trips made on a standard weekday. While trip rate is projected to remain fairly stable from 2005 to 2012, then to 2030 in Hanoi (approximately 2.6 trips per person per day). But in 2030, the trip rate is quite different among zones: in the city center the trip rate is highest and in the outer suburbs, this rate is lowest.

Men make more trip than women in both 2005 and 2012 (respectively 2.69 and 2.74 vs 2.60 and 2.66 trips per day). But in 2030, this rate decrease for both men and women because of population ageing.

Table 3. Projection of trip frequency in the Hanoi city by sex and zone of residence

Year	2005	2012	2030
Male	2.69	2.74	2.62
Female	2.60	2.66	2.58
City center	2.68	2.93	3.24
Inner suburbs	2.66	2.50	2.72
Outer suburbs	2.61	2.36	2.26
All	2.64	2.69	2.60

Source: Household travel surveys 2005 & 2012

4.2. Distance traveled forecasting

The total distance travelled in Hanoi city is increasing. The reason of this increase is that from 2008, the urban sprawl was expanded, so that the average distances travelled per person has risen from 15.4 km to 17km between 2005 and 2012 and could reach 20km in 2030. Men also travel greater distances than women.

Living further from the centre lightly increases the distance travelled in 2005, individuals residing in the central city covered an average of 14.8 km/day, while those in the inner and outer suburbs covered, respectively, 15.4 and 15.9km. But in 2030, the distances travelled by the inhabitants of city-center is greatest because the trip rate in this area is the highest among 3 zones.

Table 4. Projection of distance traveled (km/day)

Sex	2005	2012	2030
Male	17.3	19.2	19.7
Female	13.4	14.7	15.5
City center	14.8	17.5	19.1
Inner suburbs	15.4	16.7	18.8
Outer suburbs	15.9	17.9	16.3
All	15.4	17.0	17.7

Source: Household travel surveys 2005 & 2012

4.3. Estimation of average trip distance

Table 5**.** Average trip distance (km/trip)

Year	2005	2012	2030
Male	6.4	6.9	7.5
Female	5.2	5.5	6.0
City center	5.5	5.9	5.9
Inner suburbs	5.9	6.7	6.9
Outer suburbs	5.9	6.9	7.2
All	5.8	6.3	6.8

Source: Household travel surveys 2005 & 2012

We see here the average trip distance rising between 2005 and 2030, from 6.4 km to 7.5 km by men and from 5.2 km to 6.20 km by women. With regards to zone of residence, the average distance is higher in the suburbs: 5.9km compared with 5.5 km in 2005 and 6.9 compared with 5.9 in 2012, then this trends continues to 2030. In the outer suburbs, the traveled distance is forecasted decreasing in 2030 in comparison with 2020 (table 4), which may be caused by the increasing of elder population in this area. This trend is opposite in the developed cities where the elder persons prefer to live in the city center than in the sub-urban or in rural areas.

5. CONCLUSIONS

The travel demand forecasting play a important role in urban transport planning. This paper introduced one of methods for travel demand forecasting which based on demographic approach and applied for Hanoi city. One of the big great advantages of this method is that the structural effects (age, cohort) and personal travel behaviors (sex, zone of residence) were taken into account in the same model. By this way, first, we divided the population into 6 groups (2 gender groups and 3 zones) and estimated the effects of generation and age on the traveled distance. After estimating these effects and based on the projection of population, we determined the travel demand of in Hanoi city for 2030. The model results were validated by a regression between the observed values and the age-cohort model estimations. The results shows that travel demand is in a rising trend in the city until 2030 but the growth rate is different among zones of residence. City center is in the near to saturation level after 2020 and the increasing of travel demand is mainly from the sub-urban areas.

This study has limitations. First, when survey data are available only at two points in time like in Hanoi, only age and period effects can be estimated. However, period effects can play an important role, especially in developing countries. They can be estimated only when surveys are available at several contrasted points in time, and if possible, continuously on a long enough period; it allows to introduce explicitly period effects (e.g. the logarithm of real income or of relative fuel price). But period effects cannot be introduced directly as dummy variables, because of the linear relationship between the three dimensions of time: the age of an individual is the difference between the date of the survey and his/her year of birth. This difficulty can be solved by substituting life expectancy to age in a Life Expectancy-Period-Cohort (LEPC) model (d’Albis et Badji, 2017). This substitution makes sense, because with population ageing, the different stages of life cycle are longer and longer (e.g. people get married, start working, have children later than previous generations did, thus they pass their driving license and have a car later. Another limitation is the source of travel data, because of the differences in survey purposes and data collecting method, there are unexpected bias (under-reported trip, for example) in the travel demand estimations.

In summary, demographic based modeling should help for a better understanding of the relationship between travel behavior and socio-economic factors at individual level. It is suitable for long-term travel demand forecasting. Further, it would be useful to have more travel data updated and more understanding about the effects of economics factors on the travel behavior to well calibrate a APC completed model.

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