Uncertainties in Forecasting: The Role of Strategic Modeling to Control Them

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Document de travail n°97/02

Abstract

The growing concern about environmental depredations from transport activity at short-range and long-range horizon calls for policies aiming at reorientation of travel demand trends. However every transport policy is subject to risks, environmental or financial ones, and has often long-range effects. This explains the renewed interest in tools which allow detection of these risks and their consequences. There is however a methodological challenge in the elaboration of these simulation tools because we have to take into account many different uncertainties.

This paper analyzes the uncertainties attached to the forecast according to three categories: the overall estimation error from models (type I), uncertainties concerning the exogenous context (II), and uncertainties related to projection in the future of the current behavioral mechanisms (III).

The discussion relies upon a strategic model recently developed for Lyon's conurbation. This type of model offers several advantages : its structure rests on an open and flexible architecture, as on the principles of speed and flexibility of use. It is founded on an overall representation of the transport demand and supply (limited spatial division and representative description of the conditions of supply from area to area), on an innovating assembly with the taking into explicit account of feed-backs by travel purpose and on a step by step operation.

Different sources of error and uncertainty are tested and compared by means of the model. Most of them rely upon the combinations with type II and III uncertainty sources. It is argued that a strategy of systematic exploration of uncertainty is the best way to cope with it and to detect long term risks attached to transport policy. The strategic model seems a good approach to carry out such strategy of exploration.

Key-words *: travel modelling, strategic planning, urban area, uncertainty, forecasting*

Sommaire

1. INTRODUCTION

There is a growing concern about environmental depredations from transport activity at short-range horizon (regional pollution, daily life surroundings) and at long-range horizon (global climate change). This concern induces the search for policies aiming at reorientation of travel demand towards modes less harmful for the environment, or even at reducing in some ways the vehicle-miles travel intensity. However these policies encounters long-range trends in the social and spatial context : these are for instance several decades of urban sprawl, density decrease and car-ownership growth.

These long-range trends make the desired changes more and more costly and even make in some case the current situation irreversible. These growing costs are for instance those of providing mass transit in less and less dense areas or managing car-pool programs and so on. Moreover there is a risk of higher and higher social and economic costs related to the reparation of environment in the future. This is in conflict with public expenditure shortage, for instance to provide basic transport infrastructure (public transport or roads), yielding the search for social and economic efficiency of transport systems.

It clearly appears that every transport policy measure is subject to risks, environmental or financial ones, and that these measures have often long-range effects. This explains why there is a renewed interest from transport agencies in several countries in tools which allow detection of these risks and their consequences. Such tools should contribute to the elaboration of strategies reducing these risks occurrence or minimizing their consequences. This supports the need for tools allowing long-range (ten years) simulation of potential transport policies effects in an evolving and not controlled context.

Theses tools should also be flexible, allowing the test of alternative policies under contrasted hypotheses of socioeconomic context evolution (for instance economic growth, incomes, etc.). Of course the results should not be detailed forecasts of an inescapable future but rather ideas of the size of different development trends connected to the contrasted hypotheses and to different policy actions. These tools should play a pedagogical role, helping transport agencies and local authorities to confront the possible results of their action.

There is however a methodological challenge in the elaboration of these simulation tools. We have to take into account many different uncertainties but also the development path in the simulation range.

The majority of work on the errors of transport demand models and on the uncertainty attached to the forecasts made using these models, date from the beginning of the

Eighties. MacKinder and Evans (1981) showed that the main part of the prediction errors made with conventional aggregate models, came from prediction errors of the exogenous context, i.e. the urban and economic growth. A workshop of the 4th IATBR conference was also devoted to this problem (cf. in particular contributions of Horowitz (1981), Talvitie (1981) and Ashley (1981)). The conclusions of this workshop (Koppelman, 1981) were that the structure of errors interaction between the various sub-models, as well as the propagation of the errors, were badly known. The overall estimation error can be seen like the fruit of (a) the measurement and sampling errors in the surveys, (b) the errors resulting from incorrect behavioral theories and specifications, and (c) biased estimation procedures. To this overall estimation error are added the errors of context forecast to form the overall prediction error.

In this paper, we propose to analyze the uncertainties attached to the forecast according to three categories:

- the first covers the overall estimation error referred to above: there are of course errors in data measurement and sampling on the one hand, in behavioural theory, model specification and calibration on the other hand;
- the second gathers uncertainties concerning the exogenous context: economic and income growth yielding for instance car-ownership development; housing development; employment growth and locations; demographic trends yielding population less captive to public transport; time constraints evolution (work, school and facilities schedules);
- third is related to projection in the future of the current behavioral mechanisms: these uncertainties come under the potential long-range instability of travel behaviour models. For instance the coupling between car-ownership and car-mobility developments could be broken in the future; or elasticities which we know are different in short versus long-range, may significantly evolve.

The purpose of the paper is to discuss the relative weights of the different uncertainties listed above, and the strategies to cope with such uncertainties. The discussion will rely upon a strategic model recently developed for Lyon's conurbation.

In the first section we will present the strategic model developed in Lyon. The second section is devoted to the measures of various sources of uncertainty. These results are synthesized and discussed in the conclusion.

2. THE STRATEGIC MODEL DEVELOPED IN LYON

2.1 Why a Strategic Model?

In transport economics as in any scientific discipline, each model can be defined only compared to the modeled phenomenon and the paradigms to which the model refers: this makes it possible to define the application field of the model[1]. Each model thus has specific aptitudes, which are to be put in connection with the range of the needs for evaluation of urban transport policies. This range of the needs can be ordered according to two dimensions or rather two ranges, one about space and the other about temporal one.

The space range goes from the level of the neighborhood or area up to the level of the agglomeration or conurbation. The temporal range goes from the short term (1 to 3 years) to the long term (10 years and beyond). These two ranges make it possible to order the various types of studies needed to conclude a transport policy: that goes, without being exhaustive, from short-term detailed infrastructure project studies, to long-term simulation studies on the agglomeration level.

It is clear that there is no model with to do everything and that each type of study calls specific tools. It can be recognized that the analyst is better equipped with short or medium term models, as regards network assignment models or discrete choice models, than with long term models.

The long term carries in him an inherent uncertainty, with multiple dimensions. That justifies that the quantitative evaluations resulting from a long term model are interested only on a relatively aggregate space level, that is to say a few areas on the agglomeration level. In short, the strategic model must rest on regularities detected on a space scale of the agglomeration, and a temporal scale of tens of years.

The field of application of what we call a strategic model, is to be able to simulate on an agglomeration scale the consequences of varied transport policies, in contrasted urban, socioeconomic and demographic development contexts. It is not a question of providing the detailed forecasts of an inescapable future, but of providing evaluations, in the form of orders of magnitude, corresponding to these contrasted situations. Under this aspect the strategic

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[1] The example of the particles physics where the concepts of wave and corpuscle, a time in conflict, gradually seemed two valid approximations on a macroscopic scale, but incompatible between them, of the underlying nature of the matter components.

models have a teaching role towards the actors of the transport system, while making it possible to confront their visions of the agglomeration evolution.

Compared to these objectives the existing operational tools offer only few answers. The toolboxes are very well stocked but badly lend themselves to simulations of strategies. Indeed they suffer in this respect two major defects which are slowness and heaviness. The slowness of these tools rises from the objective which is assigned to them, namely the calculation of the road and public transport networks loading, which requires to use a necessarily fine spatial division (more than 100 areas for a millionaire agglomeration). That implies a considerable time of information search and of results interpretation. This level of detail weighs down the treatment of feed-backs considerably. However the degree of road congestion has obviously important impacts for instance on modal split, households residential locations or job locations, or challenges the mobility level or the car-ownership level. The taking into account of these interactions is theoretically possible but is often ignored (Stopher et al, 1996).

The concept of strategic model is not new, since for example the QuinQuin model developed in the middle of the Eighties (Bonnafous, 1985; Bouf, 1989; Tabourin, 1989; Bonnafous and Tabourin, 1995), take into account this strategic dimension of long term to evaluate the consequences of transport policies, in the fields of the financing of public transport and the congestion of the road network (Raux and Tabourin, 1992). This model remains despite everything very overall on the agglomeration and the model which we propose here wants more sensitive to space dimensions of the urban system. Strategic models were also developed in the United Kingdom, within the framework of a series of integrated studies of transport, in particular on London (Oldfield, 1993), Birmingham (Jones et al, 1990) and Edinburgh (Bates et al, 1991). These models have as a principle of functioning with a reduced number of areas, a representation of the transport supply by speed-flow relations between areas, and the taking into account of the feed-back of the supply state on the demand. One will also usefully refer to the simplified transport demand models (Ortuzar, 1992).

2.2 The Principle of the Strategic Model Developed in Lyon

The strategic model developed within the framework of the Lyons agglomeration tries to bring answers to the conditions enacted higher. The search for regularities of behaviors on the scale of ten years was done on the basis of analysis of the three households travel surveys carried out in Lyon in 1976-77, 1985-86 and 1994-95. This 20 years retrospective depth makes more solid the invariants (models specifications and parameters values) elaborated on the basis of these data analysis.

The space scale is the result of a compromise established by taking account of the acceptable degree of error, which is a function of the sampling errors of the surveys. The Lyons agglomeration includes 1,200,000 inhabitants on an area of approximately 1,000 km2. A spatial division in 25 areas was established, that is to say ten times less than for a conventional short term model. It is a division for projection of the results, which is different from a division for estimation of the sub-models, the latter restricted at the areas for which the sampling error is the smallest. This division is also different from a division for presentation of the results, in a more restricted number of areas. This restricted division allows a reduced work of networks coding and faster preparation of simulations. In addition it is compatible with municipality division on the level of which are available the socioeconomic and demographic data.

The households travel surveys, as conventional travel surveys, rest on the trip paradigm. It is not a question to be unaware of the paradigm change suggested since nearly 20 years, within the activity-based approaches. We think that the activity-based approaches are very relevant instruments when they are used in exploratory studies, in hypothetical situations: HATS (Jones, 1979), CUPIG (Lee-Gosselin, 1990) and other stated adaptations techniques (Raux et al, 1994; Faivre d' Arcier et al, 1997). These approaches are on the other hand far from providing direct implementations as regards travel choices modeling: we think besides that there is not their role, but that they contribute to the development or the test of new behavioral hypotheses, as well as guiding the amendment of the existing models.

Thus we introduced amendments, in first view marginal ones, in the conventional structure of modeling. Indeed the strategic model rests on a conventional four stages architecture where the stages of generation, distribution and modal split, are carried out at the day, while a passage to the peak hour is introduced before the assignment of trips on the networks.

The first amendment is to model trips not like such directly, but in the form of trip chains. Indeed, the preoccupation with a search for invariants of behaviors led us to reconstitute on the basis of the surveys data the trip chains, which were attached to a main purpose: for example the trips sequence home / shopping / work is regarded as a home-work chain. The surveys analysis underlined a great regularity in the generation of these trip chains by individual. In particular, for work, we note the progressive passage to «the continuous day» (no more return at home for lunch) between 1976 and 1995: from now on, on average, one home-work trip chain is carried out daily by each working individual. This stability of the trip chain generation by main purpose and area, is used as a basis for the generation model, while the variability of non home based trips is taken into account by the relation between overall mobility and income growth.

The second amendment is the step by step operation, which makes it possible to simulate and test the behavior of the modeled system in the course of time, as well as dealing with feed-backs.

The third amendment is that of an architecture modulated according to travel purposes. This modulation consists in dealing with feed-backs between stages in a different way according to travel purposes. The differences of inertia and rigidities of space and temporal behavior, according to activity types, are thus explicitly dealt with in the model.

2.2.1 Step by step operation and the taking into account of feed-backs

Instead of directly projecting the calculated situation over the horizon year (2005), the model calculates successively the situations year after year, starting from a balanced situation between supply and demand for basic year (1995). At each annual step, the travel flows (generation, distribution and modal split) are determined by the socioeconomic and demographic context of the current year, and by the transport conditions - time and costs - of previous years. The networks loading which follow from determine the transport conditions of the current year, and are used to calculate the situation of the following years.

Three reasons explain this choice:

- first relates to the internal coherence of the model: coherence between supply and demand is ensured in a process of dynamic equilibrium. It is thus not a static equilibrium of the transport system which is required, but rather a coherent advance year after year;
- second is connected with the taking into account of inertia in the behavior changes (Goodwin, 1988): thus a degradation of the travel conditions by car on a given link, will not produce immediately and for all the activities, a change of mode or destination. The inertia of the response depends on the activity type and the location or schedules constraints. Thus the architecture of the model makes it possible to differentiate the temporal step of feed-backs on the distribution and the modal split, according to travel purposes;

- the third reason rests on the interest that there is to consider the interactions between the temporal development pace of the socio-economic context and the effective implementation of transport policies over several years.

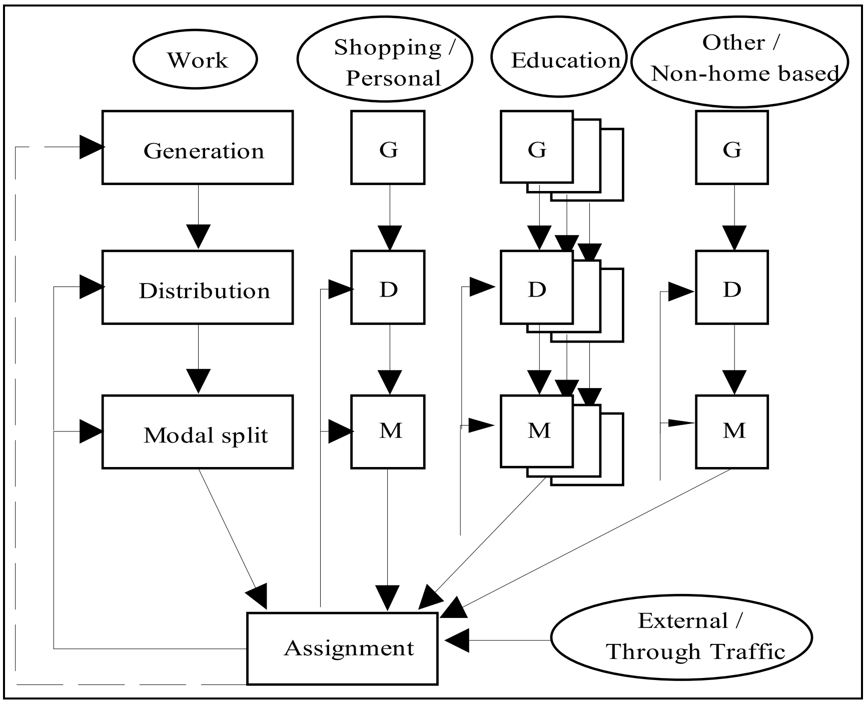
2.2.2 A break down into purposes

This break down into purposes rises from the taking into account on the one hand of determinants, on the other hand of inertia and rigidities in behavior, which are different according to activity types:

- the home-work chains: they are a function of the working population and employment locations, characterized by a strong rigidity;
- the home-education chains, by distinguishing the levels, primary, secondary and higher education: they are a function of the population and school establishments locations, as well as of differentiated transport conditions; they are forwarded to a degree of rigidity similar to that of work;
- the home-shopping or personal business chains: they are a function of the population and commercial facilities locations, with a degree of rigidity quite less than for work; the individual choice of a shopping place is relatively freer and is on-given sometimes by the modal split (one chooses initially the car then the shopping place).

The model architecture (Figure 1) allows to calibrate the different sub-models according to purposes, and to implement also different feed-backs according to purposes.

Figure 1. The model architecture



2.2.3 The sub-models

The model architecture and the flexibility of its implementation in a spreadsheet allow subsequent amendments of the various sub-models. The short description of these sub-models in their current version (SEMALY-LET, 1997a, 1997b) makes it possible to distinguish the main parameters which are sources of errors and of potential uncertainties.

The generation stage consists in calculating first of all the total of trips, all purposes and modes merged, based on a relation between average daily individual mobility and average income. This relation was established and validated since ten years on the Lyons agglomeration (Bonnafous and Tabourin, 1995).

Concurrently to this mass of trips, the emissions and attractions of trip chains by area are calculated for each of the main purposes: work, education according to three levels, shopping, other purposes. Calculation rests on generation coefficients, whose analysis of the three surveys showed convergence in the course of time, and the remarkable stability from one area to another. The emission and attraction factors vary according to purposes: total population and working one, school populations, employment by type, places of education, etc. The difference between total trips and trip chains for work, education and shopping, makes it possible to correct the emissions and attractions of trips for the other purposes and non home based trips. These non home based trips amount 21% of total trips in 1995.

In the stages of distribution, modal split and assignment, generalized travel times used rest on the following description of the supply, at the area level.

The supply in public transport is represented through the existing direct connections from area to area: it takes account of the average access time to the network in the origin area, estimated according to the network density, the waiting time, the time of course and the average egress time to the final destination. Times of course for all the origin-destinations are obtained by a research algorithm of the best route. The various components of the travel time are balanced to take account of their perception by the user, which makes it possible to obtain a generalized time: one introduces coefficients of perceived difficulty of access to the network and difficulty of waiting, as well as preference constants, expressed as differentiated access times added according to modes: these preference constants decrease according to the performance of the mode, buses, tram, subway. The values of these parameters are based on the calibration of a public transport network assignment model, validated for twenty years on the Lyons agglomeration.

The road supply is also represented in the form of an overall supply from area to area. The supply is described by the overall hourly capacity from area to area, the no-load speed and the distance between areas. The parking supply is very badly known and the very marginal parking pay, as shown by the surveys, except in the most central areas. In the absence of finer data, the parking difficulty is represented by a criterion of urban density (population and employment) which makes it possible to improve the modal split models: this synthetic criterion which represents at the same time the average search time for a place and the discomfort which is inked to it, is transformed into a generalized time (cf. infra modal split model). On the whole the generalized travel time by car includes the time of course, the search time of a parking bay, its possible cost and the cost related to the distance covered. The costs are transformed into time by means of a standard value of time (70 FF/h 1995).

The distribution stage is carried out for each purpose separately. It rests on a conventional gravity model where flows from area to area are initially calculated by

$$T_{ij}^{m^0} = E_i^m A_j^m \exp\left(- t_{ij}^m / \tau_m \right) \qquad \text{where}$$

T_{ij}^m is the number of trips from area i to area j for the purpose m

E_i^m is the number of trips issued by area i for the purpose m

A_j^m is the number of trips attracted by the area j for the purpose m

t_{ij}^{m} is the generalized multimode time (better time) to go from *i* to *j*

τ_m is the coefficient of « conductance » for the purpose *m.*

T_{ij}^{m} are calculated from T_{ij}^{m0} at the conclusion of an iterative Fratar process, so as to adjust itself with the margins in emissions and attractions. This adjustment is carried out at the time of projection, so as to avoid the use of pre-established balancing factors: we know that such factors are probably not stable in the course of time (Duffus et al, 1987).

For the purposes of work, higher education, shopping and other purposes, the conductances increase regularly during the three surveys. To take account of these developments, these conductances were connected to the development of overall car-ownership level during the three surveys, according to a linear relation: the aforementioned translated the fact that in unchanged activity location and transport conditions, trips are done at more remote distances when car-ownership level increase.

The trip distribution is left free, in the sense that an amendment of the transport conditions between areas will cause amendments of flow between areas, under the constraint of the total emissions and attractions by area. However, to take account of inertia in the changes of behaviors, it is the average trip duration of the two previous years which is taken into account in the calculation of T_{ij}^{m}. For the travel purposes more rigid in their locations, like work and education, it is the average trip duration of the five previous years which is taken into account.

The modal split is broken up into two hierarchical under-stages: the first one consists in determining the « light modes » share (walking primarily and bicycle), before proceeding to the division between car and public transport. These trips in light modes proceed almost exclusively inside each of the 25 areas, being given their range: their volume strongly decreased during twenty last years, primarily in aid of the car. The share of these light modes decreases with the surface of the area and the car-ownership level. This share is calibrated by the function

$$ML_i^m = \frac{a_m}{\sqrt{S_i}}\left(\exp(-b_m motor_i) + c_m\right) \qquad \text{where}$$

ML_i^m is the modal share of light modes for the purpose *m* in area *i,*

a_m, b_m, c_m are parameters estimated for the purpose *m,*

S_i is the surface of area *i,*

$motor_i$ is the car-ownership level of area *i.*

Once trips by light modes are deduced from the total of trips inside each area, a division is operated between the motorized modes (car and public transport) on the T_{ij}^{m} matrix. For the primary and secondary education purposes, which concern trips at short distance and the school transport supply, a constant division between public transport and car (as passenger) is operated. Indeed this division remains stable for each one of these two purposes, according to areas and in the course of time.

For the other purposes (work, higher education, shopping and other purposes) the model used is a logit model.

$$TC_{ij}^{m} = \left(1 + \exp\left(k_m + \frac{ttc_{ij}}{\tau tc_m / motor_i} - \frac{tvp_{ij}}{\tau vp_m motor_i} - \frac{d_j}{\delta_m} \right) \right)^{-1}$$ where

TC_{ij}^{m} is the modal share of public transport between areas *i* and *j* for the purpose *m,*

k_m, τtc_m, τvp_m, δ_m are parameters of the model for the purpose *m,*

ttc_{ij} is the generalized travel time by public transport from *i* to *j,*

tvp_{ij} is the generalized travel time by car from *i* to *j,*

d_j is a density parameter representing the parking difficulty,

$motor_i$ is the car-ownership level of area *i.*

This specification was selected among several concurrent specifications, offering satisfactory statistical results: it has the advantage of reconstituting the past well and of bringing a satisfactory explanation on the behavioral level. In this formulation, the car-ownership level intervenes to make more or less critical competition between public transport and car. The travel time by public transport plays a part all the more important since the car-ownership level of the starting area is high. Conversely the travel time by car plays a part of as much less important than this car-ownership level is high.

In fact zone average data are used and we know that can cause important error if one is interested in the disaggregated choice probabilities (Horowitz, 1981). However we are interested here in the average choice probability for each couple of areas. In addition the average variables from area to area are not mixed with disaggregated variables, which should limit the errors. Finally it is also the only means of taking into account the impact of the car-ownership level on the choice of the car to travel.

The passage to the peak hour consists in transforming daily flows of individuals by car, into vehicles flows at the morning peak hour, according to implicit vehicle occupation rates. Specific coefficients, calculated in 1995, are implemented for the home-work chains: these coefficients are distinguished according to a zoning into four concentric areas. For the whole of the other purposes, two different coefficients are implemented, one for trips inside the area, the other for trips coming out of their area.

The assignment is finally carried out by incorporating trips for all the purposes, as well as the external exchange and through traffics of the agglomeration: the latter are estimated according to exogenous assumptions, based on the screen-line surveys carried out in 1979 and 1990. These traffics grew of 5% a year on average at the peak hour between 1979 and 1990. The assignment is done in five iterations, with search for shorter route at each iteration. The households surveys do not allow to readjust the speed-flow curve specifically. This is why a conventional speed-flow relation form was adopted, which produces acceptable results in the reconstitution of travel times observed in the surveys.

3. AN EXPLORATION OF THE SOURCES OF UNCERTAINTIES IN THE FORECAST

This model can thus be implemented to evaluate the various sources of uncertainties referred to in introduction. After having detailed the various categories of uncertainties and the associated method of measurement, we give the results of the various tests.

3.1 Various Categories of Errors and Uncertainties Tested

We take again the distinction according to three sources of uncertainties presented in introduction:

- source of uncertainty of the type I: estimation errors of the model;
- source of uncertainty of the type II: prediction errors of the exogenous context;
- source of uncertainty of the type III: errors of projection in the future of the current behavioral mechanisms;

The methodology of the tests consists in amending in a controlled way the parameters or the exogenous entries of the model, and evaluating the impacts of these amendments compared to two points which are:

- the situation calibrated by the model in 1995, named «zero point»: in this case this situation is identical to the situation into 2005 as all the parameters of the model are blocked;
- a reference situation in 2005 corresponding to a «do-nothing» scenario: this reference scenario is a prolongation of the last tendency of development of all the exogenous entries (populations, employment, car-ownership level, incomes), without action in the transport supply.

As the impact of the amendments is measured in result of whole model operation, the resulting error is an error propagated by the model and not only the error attached to such or such sub-model.

The sources of uncertainty of the type II analyzed are the following ones:

- the reference scenario, already quoted;
- the exchange and through traffic which reflects the general economic situation;
- the population and employment which reflects the own demographic and urban dynamics of agglomeration;
- the incomes, the car-ownership level and the value of time (at the same pace as income), which reflect the development of the households wealth;
- the road supply programmed in the ten years to come, i.e. primarily a tolled by-pass of 11km length, brought into service gradually in 1997;

In practice the differences between the three types of uncertainty sources are not so strongly contrasted, as we will see it hereafter.

3.2 The Measurement of these Errors or Uncertainties

It goes without saying vis-a-vis the many outputs of the model, only some are to be privileged to compare the results of the various tests. The indicators privileged during the evaluations of the model are primarily the developments on modal share of public transport (effectiveness of the transport policy), of the total distance traveled by cars (environmental aspect), and of flows from area to area (space and social balance of the agglomeration).

The spatial division of results analysis is a division into three concentric areas: Lyon-Villeurbanne (center of the agglomeration, 500.000 inhabitants approximately), the 1st suburb and the 2nd outer suburb, corresponding each one to very different degrees of urbanization. The measurement of the gap between zero point (situation 1995) and the situation resulting from each test is made using a Chi2 distance. It is a robust criterion which makes it possible to take account of the difference between two flows on an origin-destination, while balancing each one of these difference by initial flow (zero point). In addition division in 3 areas, that is 9 OD flows, makes it possible to avoid the small values generating disturbances in Chi2. It is thus each time, a Chi2 distance between the OD matrix corresponding to zero point and the matrix corresponding to the test, which is calculated: this calculation is carried out for the matrix with all modes merged, and for each of the three modes, public transport, car and light modes.

We give as an example the values of Chi2 calculated for the reference scenario (Table 1):

Table 1. Chi2 distances from zero point for reference scenario

	All modes	public transport	car	light modes	total veh-km in morning peak hour (basis 100 in 1995)
Reference	41,084	2,684	57,505	12,525	128

3.3 Results

In order to make more easily comparable the orders of magnitude of the gaps between zero point and situations tested, the Chi2 values are given in basis 100 compared to the reference scenario, for each mode. The distance covered in vehicle-kilometers is expressed in fraction of the gap between zero point (100) and the reference scenario(128). Results are given in Table 2.

The modal shares are established, in 1995, at 57% for the car, 14% for public transport and 29% for the light modes: all equal things in addition, the results on public transport flows first, on light modes flows second, will produce gaps much more significant than for the car.

3.3.1 The exogenous context

The impacts of the exogenous context are analyzed by carrying out separate tests of the impact of each exogenous entry, in « do-nothing » development.

The exchange and through traffic evolving as « do-nothing », products to him only (test E1) a gap of a value half of the gap produced between zero point and the reference scenario, in terms of flow of all modes (46) and of vehicle-kilometers traveled (57). Population and employment (test E2) also produce significant gaps with zero point, but rather small in terms of vehicle-kilometers traveled (11). The impact of the incomes, the value of time, and the car-ownership level (test E3) produces important gaps for flows in public transport (116) and light modes (148). Car-ownership level with it only (test E5) also produces very important gaps for public transport (187) and the light modes (160). On the other hand the road supply programmed from here 2005 does not generate significant gaps with zero point (test E4). Finally a value of time decreased by half (test E6) produces important gaps for public transport (258), while increased by 30% approximately (test E7) it produces marginal gaps with zero point.

On the whole, one will note the particularly important impacts of (a) exchange and through traffic on the flows for all modes and the vehicle-kilometers traveled, and (b) car-ownership level, incomes and value of time, on public transport and the light modes.

3.3.2 The generation

The introduction of the higher value of the prediction error (with a 95% confidence) on average mobility (that is to say +0.27, test G2), yields a gap with the zero point nearly half of that of the reference scenario (all modes, 52). The combination of this prediction error with a « do-nothing » development of the incomes, car-ownership level and value of time (test G1), leads to a gap with the zero point superior with that of the reference scenario: that is true for OD matrix of all modes (103) but more particularly for OD matrix by car (167). The introduction of the lower value of the prediction error on average mobility (that is to say -0.27, test G3) leads to results similar to those of G2.

Uncertainty on the forecast of average mobility can be interpreted as well like a type I uncertainty (estimation error on the prediction) as like a type III uncertainty (future amendment of the relation mobility-income): on the whole, it plays an important part in uncertainty of the final result.

On the contrary, the introduction of variations of the generation coefficients, according to high and low values of the prediction confidence intervals of these coefficients, produces only negligible variations compared to zero point (tests G4 to G11).

3.3.3 The distribution

As the conductances of the distribution models are related to the car-ownership level, the impact of a de-coupling between the car-ownership level and the conductances was tested: the conductances are attached to the values of 1995, while the car-ownership level is supposed to evolve as « do-nothing » (test D1). The gap on flows in public transport is important (340) if one compares it with the test E5 where only the car-ownership level evolves as « do-nothing » (187). By maintaining the conductances constant, one cancels the direct impact of the car-ownership level on the spatial distribution of trips, which produces as a consequence important distortions in flows in public transport.

3.3.4 The modal split

The tests on the modal split concern, on the one hand the estimate of the light modes share, on the other hand the modal split between car and public transport.

The tests on the light modes share consisted in varying the values of the parameters *a, b, c* between the extreme values estimated according to purposes. The choice of average identical values for all the purposes (test M1) produces small gaps for flows in all modes and the vehicle-kilometers traveled, but high for public transport (103) and the light modes (106). The choice of high identical values for all the purposes (test M2) produces gaps even more significant in particular for the light modes (414). The estimate of the light modes share can thus be prone to important errors.

The tests on the modal split between car and public transport consisted in fixing the modal shares from area to area with their values of 1995 instead of letting them evolve as in the logit model. Compared to the reference scenario, the test M3 primarily produces differences for public transport (233) compared to the car (70). Compared to the test E5 of car-ownership level, the test M4 produces gaps twice less significant for public transport (93 instead of 187).

The car-ownership level thus plays a critical part in the modal split between car and public transport. All indicates that this role must be maintained and that its intervention in the modal split specification requires a great vigilance.

3.3.5 The passage to the peak hour

The tests on the peak coefficients consisted in exploiting the extreme values measured for the work purpose and the other purposes: in 1995 these coefficients vary between 0.24 and 0.44 for work, according to origin-destinations, and are worth 0.07 in intra-zone and 0.04 in extra-zone for the other purposes. The first test (P1) corresponds to a stronger concentration of trips at peak hour in the morning, and produces significant gaps from zero point for all the modes. It also implies a significant increase in the vehicle-kilometers traveled: the congestion of the roadway system involves routes reassignments on the network, therefore larger distances traveled. The second test (P2) corresponds to a spreading out of the peak and also produces significant gaps from zero point.

The variations of these peak coefficients are thus likely to produce significant impacts. A spreading out of the peak seems however most probable, like continuation of the last tendency. These peak coefficients are to be regarded here as a source of uncertainty as for the exogenous context (category II), through the flexibility of work schedules in particular.

3.3.6 The assignment and the transport supply

Two series of tests were carried out, one relating to the generalized travel times in public transport, the other relating one to the assignment on the road network.

The coefficient of difficulty of access time to the public network put at 1 instead of 2 (test A1) amounts strongly supporting those, especially in the areas where this access time is high: indeed it is about 5 to 10 minutes according to areas whereas the average time of door-to-door travel by public transport is about 30 minutes. It produces by aftereffect important gaps for the light modes (183). The coefficient of difficulty of waiting time put at 1 instead of 1.8 (test A2) also amounts supporting public transport, but in less measurement (62). On the other hand it does not produce any significant gap for the other modes. In same logic, the standardization of the preference constants at 0 minutes (test A3) also amounts strongly supporting public transport (401), without changing the other modes significantly.

They are of course extreme values which were tested, whereas, as we referred to previously, these values result from a model of public transport network largely validated by the experiment in Lyon. However these tests show the great sensitivity of flows by public transport to the values of these parameters: their importance is crucial to evaluate long-term strategies aiming at improving service quality of public transport (access, waiting, connections), rather than their pure speed.

The second series of tests consisted in exploiting on the iterations in the assignment procedure (impact of convergence) and the form of the speed-flow curve.

The iteration count (which equals 5 out of standard) does not have any impact on flows (tests A5 and A6). The curve connecting the ratio speed on no-load speed and the ratio load on capacity was deformed in various ways. The test A7 consists in making play the congestion as soon as the load reaches a quarter of the capacity of the link between areas, instead of half out of standard. This amendment produces significant gaps for each of the modes, but not for the vehicle-kilometers traveled, reflecting a shift between modes. The test

A8 consists in lowering the speed to a tenth from the no-load speed instead of two tenth when the load equalizes the capacity: this test does not produce significant gaps. The test A9 consists in a combination of the A7 and A8 tests and produces very important gaps on flows for all modes (187) as for each mode. It also produces a fall of the vehicle-kilometers traveled (-39), reflecting the impact of the marked congestion on the modal shift.

These tests show that if the convergence of the assignment algorithm does not seem to have important impacts, the speed-flow curve plays a critical part.

4. CONCLUSION

The balance-sheet of the most important uncertainty sources is as follows:

- type I uncertainties (estimation errors): in the road assignment, the form of the speed-flow curve can have a particularly strong impact on flows by car, and by aftereffect on the modal split and the distribution;
- type II uncertainties (prediction errors of the context): these uncertainties relate to the majority of the exogenous parameters, i.e. the exchange and through traffic, the working and school populations, employment, the incomes and the car-ownership level, but also the temporal rhythms of activities (peak hours);
- type III uncertainties (errors of projection in the future of current behavioral mechanisms): they are primarily the coefficients of the generalized travel time by public transport. Although the adopted standard values were validated in addition, one cannot exclude an amendment in the future of these coefficients: that introduces an important uncertainty on flows by public transport;
- uncertainties of the type I and III: it concerns the link between mobility and income, the relation between conductance and car-ownership level, as well as estimate of the light modes share and relation between car-ownership level and modal split.

The main uncertainty of the type I, here the form of the speed-flow curve, requires more thorough investigations to validate its robustness.

Uncertainties exclusively of the type II or III, can be controlled only by a strategy of «pragmatic control of uncertainty »: by this expression we understand the implementation of multiple simulations, testing a given transport policy under several contrasted exogenous contexts. It is the single means of evaluating the extent of the risks which must be assumed if a given transport policy is implemented.

Uncertainties of the type I and III can be the subject of concurrent approaches, either by trying to refine the current models, or by adopting the strategy of control of uncertainty mentioned above. This alternative can be illustrated with the example of the coupling between car-ownership level, mobility and car use. The past tendency, reflected in the specification and the calibration of the various sub-models, is that of a direct impact of the car-ownership level on the car use and the travel intensity. However one cannot exclude, in an immediate future, that the transport demand management policies can cause a de-coupling between car-ownership level and intensity of car use, by analogy with the de-coupling observed between GDP and energy consumption. However nothing indicates that the current models founded on the revealed preferences nor even the surveys of stated adaptations, are ready to provide precise estimates of the future mechanisms of behaviors. The only possible strategy thus seems to us a strategy of exploration of these uncertainties, by testing several possible specifications of coupling or de-coupling between car-ownership level and car use, like that was outlined in the previous tests.

We will stress, to finish, the advantages which this type of model offers to carry out this strategy of exploration of uncertainty. Its structure rests on an open and flexible architecture, as on the principles of speed and flexibility of use. It is founded on an overall representation of the transport demand and supply (limited spatial division and representative description of the conditions of supply from area to area), on an innovating assembly with the taking into explicit account of feed-backs and on a step by step operation. It makes it possible to connect other modules, as it is already the case with a module of polluting emission, or a module of financing and evaluation, and a module of trips external to the agglomeration.

Acknowledgments

Development of the strategic model for Lyon has been financed by the French Department of Transportation (grant n°96MT0012), Grand Lyon, Conseil Général du Rhône and SYTRAL (Syndicat Mixte des Transports pour le Rhône et l'Agglomération Lyonnaise). It has been achieved in a collaboration between LET (with Sophie Masson) and SEMALY (Vincent Lichère).

Table 2. Results of the tests

Exogenous context	Parameters amended in the model		Chi2 distance with zero point OD matrix. Basis 100 = reference scenario				
all the parameters are blocked except :			**All modes**	**PT**	**car**	**LM**	**veh-km at morning pk**
reference scenario		R	100	100	100	100	100
exchange and through traffic		E1	46	38	28	28	57
populations and employment		E2	57	68	27	52	11
income, value of time, car-ownership		E3	38	116	70	148	29
programmed road supply		E4	1	1	0	2	7
car-ownership (1.5% par an)		E5	26	187	47	160	25
value of time = 35F/h 1995		E6	53	258	25	115	-18
value of time = 100F/h 1995		E7	5	29	2	12	4
Generation							
income, value of time, car-ownership	mobility + 0.27 (higher prediction error)	G1	103	65	167	27	32
	mobility + 0.27 (higher prediction error)	G2	52	43	22	64	4
	mobility - 0.27 (lower prediction error)	G3	52	41	22	65	-4
	generation coef. work emitted 1.03 attracted 0.85	G4	0	1	0	0	4
	generation coef. work emitted 0.97 attracted 0.75	G5	0	1	0	0	-4
	generation coef. education: primary emitted 1.30 attracted 1.43 ; secondary emitted 1.24 attracted 1.25 ; higher emitted 0.91 attracted 3.4	G6	0	5	0	0	-

	generation coef. education: primary emitted 1.12 attracted 1.07 ; secondary emitted 1.12 attracted 1.15 ; higher emitted 0.81 attracted 1.25	G7		0	10	0	0	-
	generation coef. shopping emitted 0.38 attracted 11.5	G8		0	0	0	0	-
	generation coef. shopping emitted 0.33 attracted 8.75	G9		0	0	0	0	-
	generation coef. max. values work, shopping, education	G10		0	10	0	1	4
	generation coef. min. values work, shopping, education	G11		0	15	0	1	-4
Distribution								
car-ownership (1.5% per year)	conductances fixed at 1995 values	D1		1	340	25	38	7
Modal split								
	light modes factors a, b, c identical to 3, 2 and 0.5	M1		0	103	18	106	-4
	light modes factors a, b, c identical to 6, 4 and 0.5	M2		0	156	38	414	-4
reference	modal share coef. on OD 25 fixed at 1995 values	M3		98	233	70	115	93
car-ownership (1.5% per year)	modal share coef. on OD 25 fixed at 1995 values	M4		31	93	21	180	18
Peak hour								
	peak coefficient home-work = 0.5, intra-zones = 0.1, extra-zones = 0.05	P1		58	48	36	62	79
	peak coefficient home-work = 0.2, intra-zones = 0.04, extra-zones = 0.02	P2		69	118	44	77	-82
Transport supply and Assignment								
	PT access time coef. = 1	A1		27	2356	5	183	-4
	PT waiting time coef. = 1	A2		1	62	0	1	-
	PT preferences constants = 0 mn	A3		3	401	2	16	-4
	PT access and waiting time coef = 1, pref. constants = 0 mn	A4		0	28	0	2	-

	Road network Assignment, # iterations = 10	A5	1	3	1	0	-4
	Road network Assignment, # iterations = 3	A6	0	1	0	0	-
	Road network Assignment, curve 1	A7	42	26	25	32	-21
	Road network Assignment, curve 2	A8	8	27	5	3	-4
	Road network Assignment, curve 3	A9	187	127	115	191	-39

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