Exploring the use of DTA for origin-destination matrix estimation

Emmanuel Bert, EPFL - LAVOC
Dr Edward Chung, EPFL - LAVOC
Prof. A.-G. Dumont, EPFL - LAVOC

Conference paper STRC 2006

STRC | 6th Swiss Transport Research Conference
Monte Verità / Ascona, March 15. – 17. 2006

Exploring the use of DTA for origin-destination matrix estimation determination

Emmanuel Bert
Laboratory of Traffic Facilities
Swiss Federal Institute of Technology
1015 Lausanne

Phone: 021-693 23 45
Fax: 021-693 63 49
e-Mail: emmanuel.bert@epfl.ch

Dr Edward Chung
Laboratory of Traffic Facilities
Swiss Federal Institute of Technology
1015 Lausanne

Phone: 021-693 23 45
Fax: 021-693 63 49
e-Mail: edward.chung@epfl.ch

Prof. André-Gilles Dumont
Laboratory of Traffic Facilities
Swiss Federal Institute of Technology
1015 Lausanne

Phone: 021-693 23 45
Fax: 021-693 63 49
e-Mail: andre-gilles.dumont@epfl.ch

March 2006

Abstract

Traffic simulation is more and more widely used and a helpful decision tool for planer and managers. Several tools exist and could be grouped in two main families: Macrosimulators with aggregate vision of the traffic in the network and microsimulators which provide individual data. These two tools got different approaches of modeling traffic and could be use for different applications, but in some case, links or interactivities are observed depending on the inputs needed. Unfortunately and due to the differences between models, these links are not lacking of compatible problems. This paper presents a study with an innovative dynamic approach of the OD matrix determination process comparing to the usual static one. Evaluation and tests of the proposed method are presented to quantify the improvement. Using dynamic traffic assignment, developing a historical data base representing the traffic network behavior during time and finding a new matrix adjustment fitting with the data used, are the main innovative contributions of this work.

Keywords

Traffic simulation – Origin-destination matrices - Dynamic traffic assignment– Route choice behaviour – 6th Swiss Transport Research Conference – STRC 2006 – Monte Verità

1. Introduction

Traffic simulation is becoming a more and more widely used tool in many transportation researches and studies. Road network modelling can evaluate and quantify scenarios which have been generated and help transport managers in operational and planning studies. This is a helpful decision tool for short, medium and long term studies but not a perfect representation of the reality.

Two main different families of simulator could be distinguished. On one hand, macrosimulators or urban demand planning software (EMME2, VISUM, AIMSUN Planner, etc.) use a traffic flow model ([4], [5]). They evaluate the spread of the traffic on the network. On another hand, there are microsimulators which describe the traffic assignment or itineraries choice of the drivers on a network. The later (AIMSUN, VISSIM, etc.) uses an individual and disaggregate representation of the traffic ([1]). The microscopic simulator can model user's behavior on the road with the help of different laws which define interaction between cars.

In the early days, only macrosimulation tools were available for traffic studies. This kind of tools uses simple algorithms and work by iterations. Macrosimulators provide global results for long term traffic prediction particularly for planning studies. Later, with the growth of the computer science and the knowledge of the traffic laws, microsimulation has been developed to evaluate more in details the traffic behaviour and particularly the dynamic aspect of flows. This leads to microsimulation being increasingly used for different types of traffic studies and particularly for assessment of ITS applications.

Even if microsimulation could be considered as an evolution of the planner approach, these tools are complementary in practice. Each kind of simulator has its strength depending on the objectives of the study. For planning of large road network, macrosimulation is better adapted, whereas for smaller study area and for operational problems, microsimulation provides more detailed outputs.

Moreover, depending of applications, outputs of one tool could be use as input for another. This way certain interactivities link the different tools; but "bridges" between simulators are not without problems and deficiencies. Approaches and conceptions are different and passing from one tool to another is not so easy. Data format and quality could be quite different to compromise a good utilization. This statement justifies the aim of this research. A symbiosis use of the both simulators can lead to a more adapted process and efficient interactivity and an easier utilisation.

To find this new process which allows a better link between macro and micro data, actual practice is going to be analyzed to identify the possible weaknesses and to develop a new one which match better to the microscopic needs.

Evaluation of this new method and relative improvement and comparing with the usual process will be analyzed. The benefits or issues expected could be in term of quality of the demand representation. This new demand must allow providing a dynamic and representative traffic modelling. The whole Macro-Micro process becomes more integrated to save time in calibration and money with an increasing outputs quality ([12]).

The first part of this paper presents the difficulties of using different traffic simulation tools. Then, some interactivities are going to be presented, particularly in case of microscopic simulation analyses and deficiencies. And, the actual link between macro and micro and a new process to do it will be analyzed. Finally, main issues in this research will be discussed followed by preliminary conclusion.

This is an ongoing PhD research that started this year, partly explains why this paper proposes different approaches or methods without any results or final conclusion. The presented research is still in development and could change depending of the further works or investigations.

2. Simulation tools

To analyse interaction between different types of simulators and the origin destination (OD) determination process, traffic simulation situation must be study. Simulators and traffic planer softwares will be considered in general and macrosimulators and microsimulators in particular. Detailed approaches, inputs needed, outputs expected, mathematical models, functionalities, characteristics, differences and complementarities will be analysed.

However, except the level of detail, the most important distinction that has to be highlighted is the time dependent characteristic of microsimulators in comparison to static one of macrosimulators. Indeed, demand is represented as a unique OD matrix in the later case while a time varying one is used in dynamic models. This difference has obviously a direct impact on the traffic assignment process.

Hence, depending on the practical use of the kind of tools (investigation must be done with planer and manager users), the different fields of utilization of each tool will be defined and studied. Particular attention will be done on process, tools, and data needed for a microscopic analyze.

2.1 Macrosimulation

This kind of tools is usually called, forecasting model. This is due to the fact that there are mainly axed on the future utilization of the network infrastructure. These models try to represent the real world by simplification, the expected utilization of the network by drivers depending on the supply. They represent the traffic with global value for each network's link (density, mean speed, flow) based on fluid mechanic. Usually, with this model, traffic distribution and the level of details are not really satisfactory.

With a global and aggregate vision of the network, macrosimulation could solve problems linked with long term transport planning purposes. First, by simplification of a complex and global situation, it allows a better understanding of the situation. This tool helps planers to analyze, control and represent the huge quantity of data linked with a transport system and its network. The number of drivers who will use the new road or infrastructure could be estimate with this tool.

In macrosimulation, the traffic distribution is defined as a static equilibrium. For each link and turn (turning corresponding to a specific move at an intersection), a function is defined depending on the geometry, the road type and the type of flow. This function named volume-delay function gives for each flow value (vehicles per hour) the travel time needed to cross the link. The function takes into account the travel time in free flow and the augmentation of this time due to the volume of the traffic. The route choice is dependent on the link cost (travel time plus eventually tolls, etc.) between the origin and the destination. An iterative process allows taking into account all the different drivers in the network at the same moment. The chosen itinerary takes the combination of the shortest link cost depending on the traffic density and the road used. Then for all the origin destination pairs, the total travel time is known and optimized to a global trip minimum ([9]).

2.2 Microsimulation

Microsimulation, as the name suggests, looks at the microscopic aspect of the traffic. Individual behaviours of each user of the network are modelled and provide information of all the physical proprieties of the vehicle (position, actual speed, distance between cars, pollution emission, acceleration, deceleration, etc.). A microsimulator can represent different driver behaviours and car movements in the network as well as real dynamic traffic phenomena. This kind of simulation allows dynamics variations of the demand and the supply (accident, variable message signs, parking, etc.). Hence, it is an efficient tool to provide outputs useful to road network operational studies even if large network calibration needs time and experience.

Dynamic traffic assignment (DTA) is applied in microsimulation models ([8], [10], [11]). Routes are assigned to the vehicles entering the network according to the traffic conditions. Traffic conditions are represented by a cost for each link of the network. These costs are mainly calculated on the basis of the average travel time experienced by the vehicles that covered the link in the previous time periods and also the hierarchical considerations (theoretical capacity) of the used links. In this way, the cost represents a kind of attractive effect of the link. This allows vehicles using the shortest path computed by taking into account the current conditions. A sort of dynamic equilibrium is then obtained. Thus, it can be shown as a reactive assignment, route choices being adaptive.

After calculation of the hypothetic paths between origin and destination by DTA, route choice allows different car affect possible on these paths. Models determine the distribution of the traffic demand on chosen itineraries. Logit and C-Logit models are the most used; the later is an extension of the first, but penalising overlapping situations.

From this itinerary choice, vehicles go into the network and moves must be modelled with representative behaviour. This behaviour must take into account different fix and variable constraints; fixed constraints such as network configuration, fixed (priorities, stops, yields, etc.) and variable constraints such as adaptive traffic signals and interaction of the different user of the network. To deal with the last point, several rules exist. “Car following” law defines how the different cars following each other. Safety distance between vehicle, acceleration and deceleration are depending on the parameters defined by the “car following”. Concerning the changing of direction in the network by using lanes in a link, the “lane changing” defines the main characteristics. Speed differences for passing, gap acceptance, waiting time before lane changing, etc. are fixed by this law.

3. Tool’s interactivities

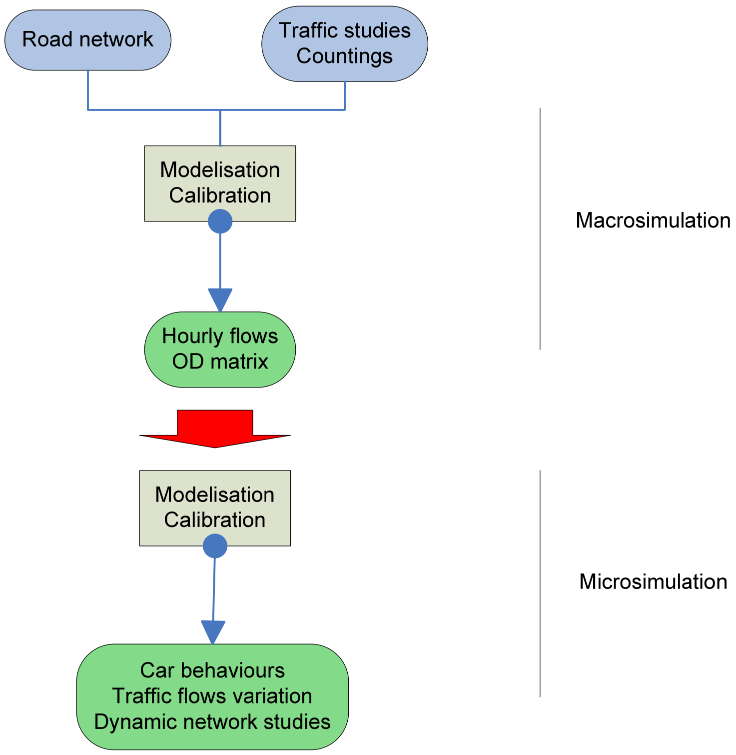
3.1 State of the Art

As explain in the introduction, even if each kind of simulator has its proper applications, some interactivities exist. In some cases, outputs of one tool could be use as input of another tool. By this way, tools are complementary and can work with serial or parallel approaches. From this situation, studying the state of the art in term of interactivities between tools could be interesting. In the literature, several references linked with the interaction for the macro and micro simulators could be found. Two principal researches axes could be identified. Firstly, combination of the two types of simulators is researched in order to simplify the network modeling. Researchers try to standardize the network model code to be readable by microscopic and macroscopic softwares. Secondly, references treat about traffic and moves representation on hybrid models ([2], [3]). To simplify the modeling and to minimize computation time, traffic is represented by flows (like in macrosimulation) in areas where details is less needed and by individual car representation (microsimulation) for a finer analysis of the moves in particular places (junction, freeway exit, bypass, etc.).

3.2 Macro/Micro process

Let’s see more in detail the process from trip generation modeling to dynamic analyses via OD matrix determination. As shown in the figure 1, to do a dynamic and detailed study, depending on the demand (behavior of the traffic on the network in case of changing configuration like accident or to test adaptive traffic light), usually, you need to use macroscopic outputs. Whereas, to determine just origins and destinations of the drivers and let free the itinerary to link them to modeling a real route choice behavior, you need to do a complete macroscopic study. Based on road network and demand poles (centroïds, modeled places where cars go in and go out of the network) modeled and on measured traffic counting, macrosimulators is able to determine an OD matrix representing flows between each centroïds. This kind of data is needed for a microscopic simulation. Then, from this OD matrix, microsimulators evaluate dynamic traffic variations in the network. Microsimulation outputs could be cars behavior, traffic flow variations, dynamic analyses, etc. depending on the needs of the study.

Figure 1 Macro-Micro process



3.3 Deficiencies

About this link, we must note that a lack could be observed in "communication" and interaction between the traffic planer who is evaluating an OD matrix and the operations manager, user of this demand as input during microscopic analyses. Recurrent problems could appear due to a different vision or approach in traffic demand evaluation. Macroscopic users approach OD matrix determination with a planer goal and a long term, global and static traffic evaluation. During microsimulations, dynamic traffic characteristics are very important to analyze, as accurate as possible phenomenon linked with the different flows and their variation.

This link could be problematic. If outputs of the first tool are not accurate enough or not adapted for the second tool which will use these data as input, the final results extracted from the second tool could not be representative, even in case of good utilization. And typically, in our case, if the demand determined by macroscopic study does not represent the real traffic with a good accuracy, analysis of the network by microsimulation could not be realistic due to the inexact traffic volume between origins and destinations.

Actually, the optimization of the global macro/micro process by improving the quality of the macroscopic outputs (matrices OD) to match better the requirements of a fine study by microsimulation by using the positives points of each approach hasn't really been developed.

Usually, OD matrix determination for microsimulation inputs is done by using a macrosimulator and its OD matrix estimation by static equilibrium. This method has been developed to solve the problems of traffic forecasting in long term. The static aspect of this method is more adapted to flow equilibrium on a network than to represent the dynamism of the traffic in front of a short term impact action.

From the statement of this interactivity problem, in the second part of this paper, actual method to estimate the microsimulators inputs are going to be explored and an innovative proposition will be proposed.

4. OD matrix estimation by static equilibrium

4.1 Process

After simulation interactivities evaluation and highlighting the lacks, analysis of the OD matrix estimation by static equilibrium must be done.

The process described below is the common approach for OD matrix determination used for traffic studies. Several tools could be use for this task, the must known and used is perhaps EMME2 from INRO (Canada).

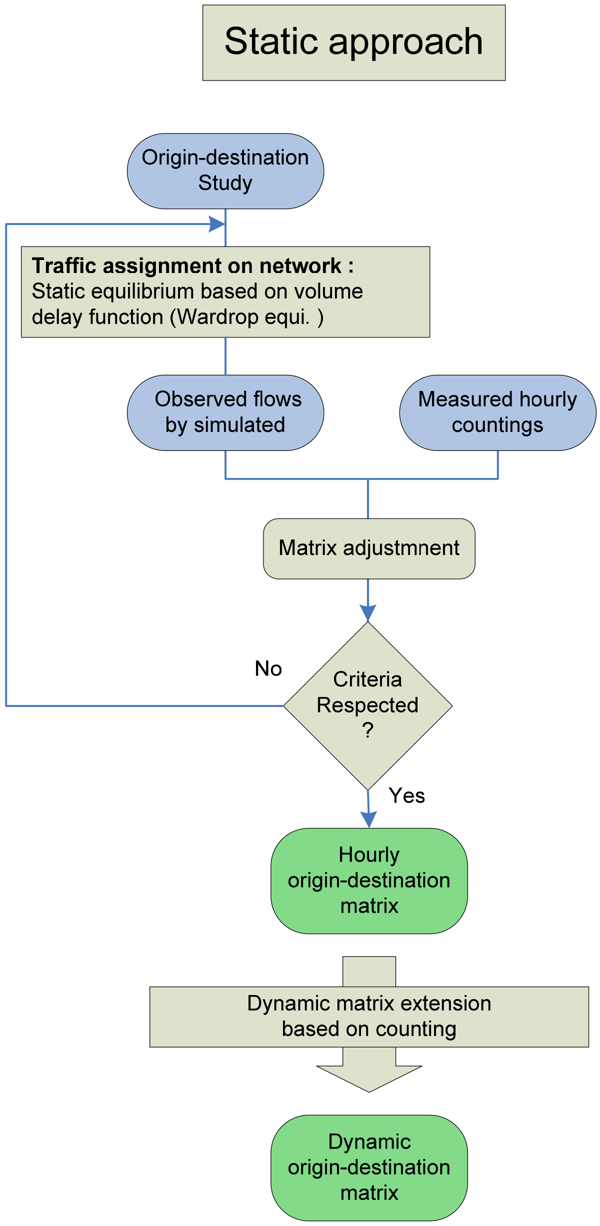
Several points are determined during this estimation. Based on a first evaluation of the main traffic flows (obtain by questionnaires, studies or investigations in situ), an initial matrix origin-destination is created. The structure of this matrix depends on the quantity and quality of data collected. Then, traffic assignment must be made; finding the best path between an origin and a destination is done using a static equilibrium. As previously explained, to evaluate the different paths, each sections and junctions is characterized using a function which defines the travel time (to cross the section or the junction) depending on the traffic flow on the link. This function is named Volume Delay Function. From the Wardrop equilibrium, traffic is shared out on the different possible itineraries in order to minimize the travel time. By this way, all the vehicles with the same origin and destination are going to do the same travel time, but not necessarily the same path. This is a global optimization of the journeys.

Based on the explained distribution of the traffic and on in situ measured flows, an adjustment of the initial matrix could be done. This is an iterative process and its goal is to minimize the “gap” between the observed flows by simulation and the real flows. This optimization tries to find a compromise within these two data sources and taking into account criteria (previously defined) which fix the characteristics of this compromise. Then from this step, the OD matrix which modeled the demand of traffic on the network is obtained.

All this process is static. It represents moves for one time slice (say one day) with constant demand and traffic conditions. This is average output for the determined period.

To use this OD matrix as an input of a microsimulator and then do a dynamic traffic evaluation with a time dependant demand, it must be extrapolate based on counting in the network. Nevertheless, depending on the measured data, this technique does not allow representing the possible variations of the matrix structure by time (non uniform modifications changes on matrix values).

Figure 2 Matrix OD adjustment by static approach



4.2 Developers

Static adjustment approach is the most common method for OD estimation and particularly for microsimulation with route choice input determination. This method is based on works of several main contributors. Few of them are presented here with their work.

To begin, the Wardrop equilibrium (1952) is the first hypotheses of this process. It says “Under equilibrium conditions traffic arranges itself in congested network in such a way that no individual trip maker can reduce his path cost by switching routes”. An alternative way of assigning traffic onto a network is express in the second principle “Under social equilibrium conditions traffic should be arranged in congested networks in such a way that the average (or total) travel cost is minimized” ([13]). The static equilibrium is based on this principle and lead to a user’s equilibrium or selfish.

To evaluate this travel cost, different factors (tolls, fuel, etc) could be considerate but, usually, the main part of this cost is constituted by travel time. From this statement and to allow assignment, the relationship between the speed on a link to its flow has been studied and established. Highway Capacity Manual (HCM) determines different volume delay functions for numerous different roads or intersections. This handbook gives these data depending of the road types (freeways, rural, suburban highways and urban streets), the conditions (roadway, traffic and control conditions), etc. Several groups of function have been developed to improve the accurate and to match better with the traffic and the infrastructure. We can site 1985 HCM, 1994 HCM, BPR (Bureau Public Road), Akcelik or Spiess (conical) curves.

Finding the shortest path in road network is done using algorithms. The two basics ones have been developed by Moore (1957) and by Dijkstra (1959) to allow efficient process and computing.

To obtain realistic demand, this traffic distribution must be combined with the observed flows. Spiess has particularly worked on the field of matrix adjustment and his paper “*A Gradient Approach For The O-D Matrix Adjustment Problem*” (1990) could be considerate as a reference in the domain ([7]). This paper presents a mathematical approach which formulates a convex minimization problem. With this process, the original OD matrix is not changed more than necessary by following the direction of the steepest descent.

Evaluation of the obtain matrix is important to provide a representative demand. Bierlaire worked on testing the quality of OD matrix. His paper “*The Total Demand Scale: A new measure of quality for static and dynamic origin-destination*” (2001) proposes a new method for measure the quality for OD trip tables estimated from link counts ([6]). This method, called the Total Demand Scale, is based on the assignment matrix used to determinate the estimated OD trip table and this OD matrix itself. It measures the under-determination related to the OD estimation problem, considering only the underlying route choice model and the network topology.

5. Dynamic OD matrix estimation

5.1 Problems

As explain previously, disadvantages or lacks of the method explained above can lead to outputs not adapted or incompatible for an exploitation of the data by microsimulation. The static equilibrium does not allow a time dependant traffic variation which is adapted for dynamic flows modifications (essential for short term microscopic studies).

To solve this problem, this part is going to deal with an innovative approach for OD matrix estimation. With this new method, the demand is going to be determined by a dynamic approach integrated in the adjustment process.

5.2 Process

First, like in the static determination, initial matrix OD obtained from surveys is used to determine a "picture" of the traffic. This draft demand is used as input to find the traffic distribution in the network. The more detailed is the survey; the more detailed and accurate will be the initial matrix and thus the final results. Of course, in most of the cases, this kind of data is difficult to get, particularly for large study area. Ideally, this database must gives information for the different kind of driver, kind of trip, time slices, etc. The matrix is deducted from these data by using trip generation and distribution modelling.

Dynamic traffic assignment (DTA) will spread the traffic generated by the initial matrix through the network. For that, after network modeling, parameters (mainly road hierarchy) needed for DTA have to be determinate. This simple "calibration" allows determining traffic distribution. DTA is based on the minimization of the individual journey cost (as explain on 2.2) and is usually used in microsimulation to deal with dynamic phenomena. Contrary to static traffic assignment by volume delay function, which taking into account the flow equilibrated on one link for the time period, DTA uses costs determined with flows observed during the past simulation step. By this way, traffic assignment is adapted to the actual traffic conditions.

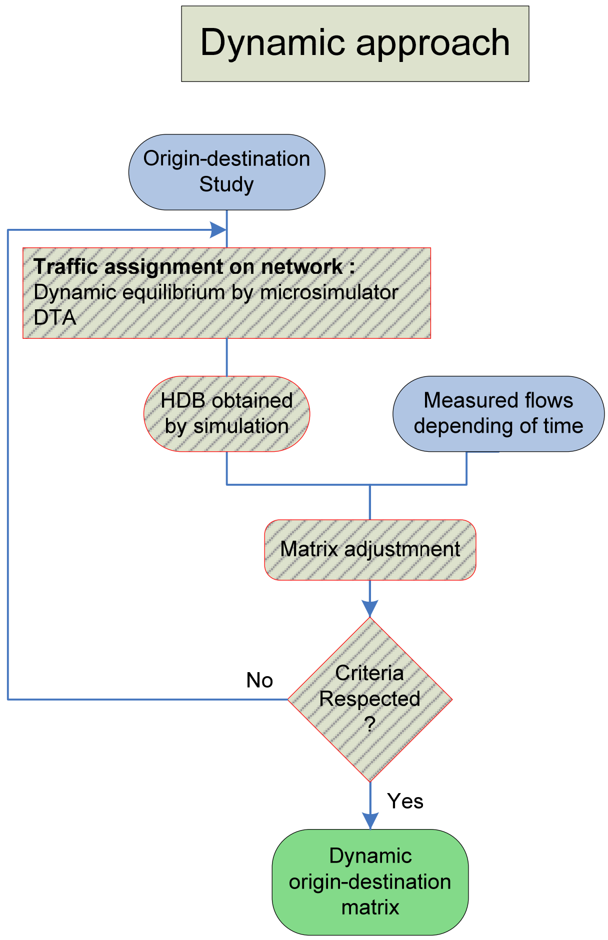
Then, a method to determine a historical data base (HDB) has to be developed based on this distribution. These data take into account the different flows in the network and several different simulations (different seeds representing different daily traffic conditions). By this way, not only one day or seed is represented by the HDB but the usual state of the network. An iterative learning process will lead to obtaining this average but also time depending behavior of the traffic network along the study time. Dynamic flows for each link will be determined for one seed. This first data base will be combined with data from other seed (average of *n* seeds). Then, flows data are going to be smoothed by averaging with one or several past data (flows observed on previous simulation step). An optimal combination of the past costs (cost observed in previous time periods) and the daily differences (data from different seed or stochastic parameters input) must be determined to obtain an adapted and representative input for the next step.

This HDB represent the traffic condition in the network from the simulation based on initial OD matrix; these data must be compared to the observed traffic in situ to determine the real demand.

A new demand adjustment method will be developed to determine the optimal matrix which takes into account the different fixed criteria. Criteria, which define the characteristics needed and usefulness of the final OD matrix, will also be deeply analyzed (respecting the flows in the network and the structure of the initial OD matrix). These criteria must be determined taking into account the level of detail needed, the quantity and the aggregation of traffic counts, the quality of the OD survey and thus the initial matrix (representative, details, etc.), etc. One's again, a minimization of the difference between the HDB and the dynamic flows measured in situ (time depending flows) will be done. The best compromise between the two inputs must be found depending on the criteria. Of course, the result of the minimization must be under a certain limit to be accurate enough to represent a realist traffic demand. If not the inputs must be completed or reevaluate. This adjustment method has to deal with time and these two data bases. Optimization between HDB and counting could be done for each time slice. In this case, time slice size must be defined depending of the inputs quality (initial OD matrix, counting, etc.), the level of detail expected, the maximum disaggregating allowed (too small slices could lead to inconsistent results) and the limits of the method. A link between results of each time slice must be established (logical evolution of the traffic, etc.) to obtain a consistent, continuous and smooth final dynamic OD matrix.

Compared to the past process, this approach leads to obtain directly and by an integrated method a dynamic OD matrix.

Figure 3 Matrix OD adjustment by dynamic approach



Hatched boxes show points which need particular development.

The OD matrix obtained must have different qualities. The goal of the method is to find the closer demand as observed on the network. The matrix must represent the different characteristics of the traffic. First, trip generation and trip distribution must be as close as possible as the real journey of the driver through the network. It means that the volume of generated user and the entrance and exit places must be right. After, the dynamism of this demand is very important. It must follow the variation of the volumes generated for each origin destination. Depending of the kind of trip (work, leisure, etc.), the evolution of these volumes is not similar. Inputs quality can strongly influence this dynamism aspect.

5.3 Issues

After developing these steps, an evaluation method must be done to judge the opportunity of the new method and to see the contributions of this research in the traffic simulation field.

The static and the dynamic OD matrices have to be compared in term of quality and representative. OD matrices must model as close as possible the real demand in the network. The aim is to highlight the different advantages (and eventually the disadvantages) of the implementation of a dynamic OD matrix in the process and not adjusted at posteriori and of the process itself. To do, a new OD matrix evaluation tool has to be developed for these two methods. For adjustment by static equilibrium, several tools exist but these have been created for static assignment. There over, a unified method needs to be developed to evaluate the OD matrices from both approaches.

Several applications could be done to estimate the benefit of the new OD determination method.

Dynamic quality of the outputs of different approach will be tested and evaluated by microsimulations. Several scenarios will be developed to test if the demand is representative, well defined and adapted for a microscopic study. Dynamic properties are going to be investigate by analyzing the built up and distribution of congestion on the network during rush hours, the behavior of the traffic in front of an accident, the creation of a traffic jam due to an accident and the dissipation of the queue, creation, variation and evolution of length of queues, etc, compared with observed behavior.

The OD matrix obtained by dynamic adjustment could be used as input of a microscopic simulation. With this test, the behavior of the demand could be analyzed and the gain in calibration time could be quantified. This evaluation could be done with a simulator using the same DTA process (use simulator X for the DTA and test the matrix with the microsimulator X) or not (X and Y). Both results could give information about the compatibilities of the approach depending of the different tools used.

This new OD matrix can also be used as input (initial matrix, instead of the origin-destination study) of the OD adjustment by static approach. Traffic assignment on the network (number of iteration, equilibrium stabilization, etc.) and matrix adjustment (compromise between flows from the matrix and counting) can give relevant information about the quality and the representatives of the matrix. Finally, from the new OD matrix obtained, flow comparison can allow to see the "position" of this result comparing to the common static approach output and real data counting.

It's important to note that the different issues of the process are linked with inputs used. The quality and the quantity of the initial OD matrix (obtained by studies and investigations) could be very different depending on the origin of the data. Data used to determine this matrix could have different structures or shapes. Depending if data give information for each kind of travelers, for each arterial or for each time slot can change completely the complexity of the matrix's structure. Depending on these data, dynamic aspects (structural variation of the matrix depending on the hour) could be more or less included in the input. The dynamic matrix extension based on counting (cf. Figure 2) could be more or less precise depending on this data quality.

The different task planned could be summary as follow:

- Building an initial OD matrix.
- Appling DTA with this OD matrix in the network.
- Creating an HDB based on this DTA.
- Demand adjustment.
- Evaluation of the dynamic OD matrix.

6. Conclusion

Traffic simulation is more and more widely used tool for planer and managers. Several tools exist and could be grouped in two main families: macrosimulators and microsimulators. These two tools have different approaches of the traffic and could be use for different applications, but in some case, links or interactivities are observed depending on the inputs needed. Unfortunately and due to the differences between models, these links are not lacking of compatible problems. Then, this paper presents a study with an innovative dynamic approach of the OD matrix determination process comparing to the usual static one. Evaluation and tests of the proposed method are presented to quantify the improvement.

Different steps and developments of this approach constitute real new contributions to the simulation domain and particularly the traffic demand estimation and modeling.

The approach is by itself particularly innovative, principally by the dynamic traffic assignment of traffic through the network. The idea of using this dynamic process to find the distribution of the traffic depending on the initial demand represents the advantage of meeting the needs of next step, microsimulation studies.

The construction of the historical data base is an interesting challenge and useful in this context but also for other applications. The choice of the optimal between the utilization of the past cost and the cost from different days (from different stochastic seeds) can lead to a data base useful for planners. These data provide an average utilization of the network taking into account the smoothed traffic and the variation in time. This is a kind of “time dependent” static equilibrium.

The new matrix adjustment method has to deal with dynamics or time dependent data bases. For each time slide and for each section, the process must determine the best value depending on the historical data base value and the observed value. This method treats the two data bases just like in the static case but with the time variation of the values too (one more dimension added).

The last contribution of this work is the development of new evaluation and comparison processes to test the matrices obtained with the different approaches. A methodology has to be established to highlight and analyze the different qualities needed for a good utilization of the data.

7. References

[1]. Barcelo J., Casas J., Ferrer J.L. (…) AIMSUN: New ITS Capabilities

[2]. Bourrel E. (2003) Modélisation dynamique de l'écoulement du trafic routier : du macroscopique au microscopique, *Thèse*, France.

[3]. Bughout W. (2004), Hybrid microscopic-mesoscopic traffic simulation, *Doctoral Dissertation Royal Institute of Technology*, Stockholm, Sweden.

[4]. INRO, The EMME/2 Transportation Planning Software : Modelling and Analysis Features, www.inro.ca.

[5]. Nathanail T. (…) Dynamic traffic assignment through macroscopic and microscopic modelling with EMME/2.

[6]. Bierlaire M. (2001), The Total Demand Scale: Anew measure of quality for static and dynamic origin-destination trip tables.

[7]. Spiess H. (1990), A gradient approach for the o-d matrix adjustment problem.

[8]. Cascetta E., Cantarella G.-E. (1991), A day-to-day and within-day dynamic stochastic assignment model.

[9]. Friesz T., Bernstein D., Smith T.-E., Tobin R.-L., Wie B.-W. (1992) A variational inequality formulation of the dynamic network user equilibrium problem.

[10]. Torday A., Bert E., Dumont A.-G. (2004) Route choice relevance in complex urban network micro-simulation models, *4th Swiss Transport Research Conference*, Monte Verita / Ascona, Swiss.

[11]. Bert E., Torday A., Dumont A.-G. (2004) Historical based traffic assignment in microsimulation for advanced traveller information systems assessments, *ITS World Congress*, Nagoya, Japan.

[12]. Bert E., Torday A., Dumont A.-G. (2005) Calibration of urban network microsimulation models, *5th Swiss Transport Research Conference*, Monte Verita / Ascona, Swiss.

[13]. Dios Ortuzar J., Willumsen L.-G. (2004) Modelling Transport Third Edition**,** *John Wiley & SONS, LTD*