Calibration of urban network microsimulation models

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Abstract

Microsimulation is increasingly being used for different types of traffic studies and particularly for assessment of ITS applications. This paper explains how a large urban network, the case of Lausanne, has been calibrated with the microsimulator AIMSUN, in order to find results similar to real counting. The different parameters which can be tuned for achieving this goal are described. Vehicles behaviours, network modelling and traffic assignment are tackled. In the former, dynamic traffic assignment and route choice are particularly analysed.

Keywords

Microsimulation – Calibration - Dynamic traffic assignment– Route choice behaviour – 5th Swiss Transport Research Conference – STRC 2005 – Monte Verità

1. Introduction

Traffic simulation is becoming a more and more widely used tool in many transportation researches and studies. At the first times, only macrosimulation tools were available. They were mainly developed for planning purposes and are still used for this type of projects. Nevertheless, with the growth of ITS applications, the need for dynamic models has been rapidly emphasized. The development of microsimulation models has consequently been strongly motivated by the necessity of having the use of new tools being able to be dynamic for ITS applications. For the assessment of Advanced Traffic Information systems (ATIS) for example, using dynamic models like microsimulators is essential. This type of projects aims generally to estimate the benefits that can be expected from ATIS applications. Comparison between informed vehicles route choice behaviour and non informed ones are usually done.

In macrosimulators, traffic is generally described as flows defined by behavioural rules based on the mechanic of fluids. On the other hand, microsimulators models provide individual representations of the vehicles driving along the network. Behavioural rules are mainly based on the interaction of the vehicles with each others and with the infrastructure (car-following and lane changing models for example). However, 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 Origin - Destination (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.

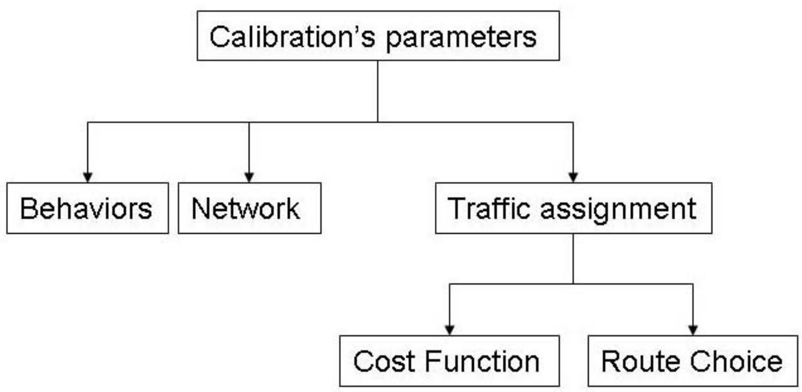
A microsimulator has to represent the different driver behaviours and car movements in the network as well as real dynamic traffic phenomena. Therefore, different steps should be done to carry out a microsimulation project. Different kind of information as input is needed. Firstly, the network configuration (links, lanes, junctions, turns, fixed signals …) has to be edited and the different traffic light control algorithms (fixed or adaptive controls with or without bus pre-emption, VS Plus [1] or other) to be coded. Secondly, the Origin - Destination matrix must be generated in order to charge the network with traffic. After these steps, the model is calibrated on the base of observed traffic data. The aim of calibration is to reproduce traffic conditions as close as possible to the real field observation. The compared traffic performance measures are traffic flows, link travel time, OD travel time, congestions level, etc. There are many parameters that can be tuned in order to represent the real behaviour of the driver in the network.

The AIMSUN microsimulator, a tool developed by the Polytechnical University of Catalunya in Spain [2], and particularly its traffic assignment, has some distinctive features which may imply some difficulties for model's calibration. Indeed, vehicles get a perfect knowledge of the geometrical network (links) and traffic conditions (due to the dynamic traffic assignment). In the simulator, traffic conditions are actuated values, but drivers don't know these values in reality and they won't be influenced like in the simulation. Generally, drivers use only their own experience to choose a route in the network.

All these calibration parameters are in complete interactivity. Thus, they have to be evaluated simultaneously, in parallel. It's not possible to fix one and to try to set the others later. This distinctive feature makes calibration a complex and non-deterministic task. Consequently, a good experience of the simulator and of the network (knowledge of the traffic in the city) is required.

In this article, an explanation of one of the different possibilities of calibration is suggested for a large network, the case of Lausanne and its agglomeration. Process is described followed by a concrete application for the specific use of the AISMUN microsimulator. However, the generic method and the approach described can be extrapolated for other type of microsimulators. Firstly, the Lausanne network is presented, then, different problems, regrouped in different categories (as shown in Figure 1), and proposals to solve them are shown. Finally, some results and comments on further research trends are given.

Figure 1 Calibration's parameters grouped

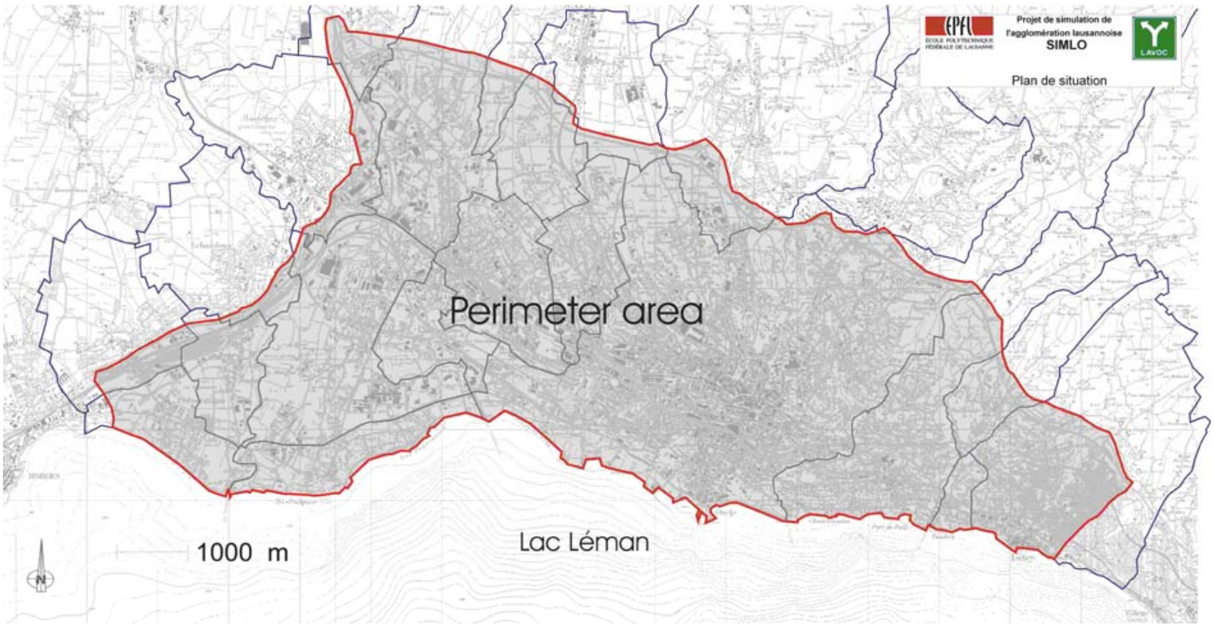


2. Lausanne network

The calibration's study presented in this article is based on the Lausanne city and its surrounding's network. This is a 15 km x 7 km (100 Km^2) perimeter area representing a dense network where all the roads have been considerate (except dead ends or without possible transit roads). Congestion during evening rush hours can be considered as moderate even if, some arterials are over loaded (particularly on the city centre exits and entrances).

Figure 2 represents the modelled network in grey and the commune's limits in blue.

Figure 2 Situation of Lausanne network



The different characteristics of the network are summarised in the following table (see Table 3).

Table 3 Lausanne network characteristics

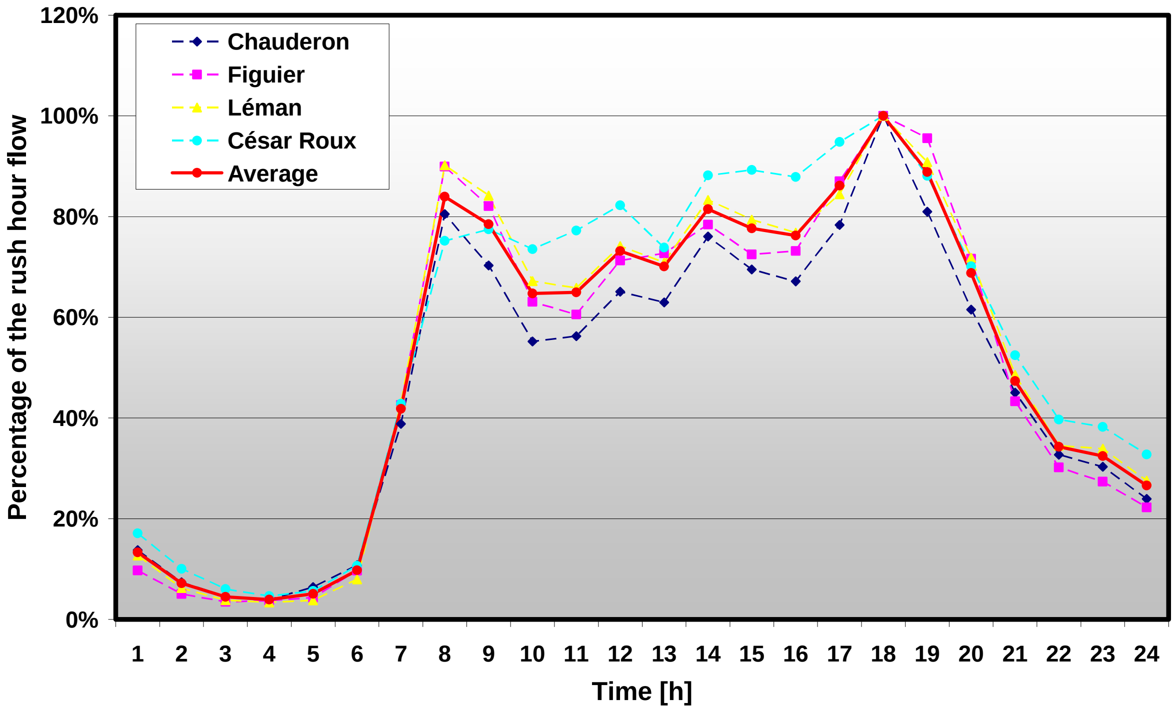
Sections	16'006
Polysection	4’131
OD Matrix size	292 x 292
Nodes	1613
Traffic light	148
Rush hour [veh/h]	61'594
Simulation period	16h00 – 19h00

In AIMSUN, there is a special distinction between a section and a polysection. The former one is a combination of straight sections. In the present network, polysections are formed by four sections, in average. This represents dense network with short distance between junctions.

The network has been modelled with all the horizontal and vertical signalisation and adapted traffic light with VS Plus algorithmic in the Lausanne’s limit and with fixed settings in the rest of the network.

The original matrix for the network has been provided with the help of the macroscopic EMME/2 software. It was a static one hour matrix for the peak evening period. To simulate the evening rush hours between 16h00 to 19h00, the shape of the dynamic demand has been based on the graph of the mean avenues flows of the city of Lausanne surrounding these hours (see Figure 4). The dynamic version of this matrix is represented by a sequence of 12 fifteen minutes matrices. EMME/2 matrix has been multiplied by a numbers between 0.78 and 1.05 to obtain the different matrices of the dynamic one (see Figure 5).

Figure 4 Evolution of the measured traffic demand in several places in Lausanne



Only the part between 16h00 and 19h00 of the daily graph has been considerate to determinate the dynamic matrix.

Figure 5 Evolution of the EMME/2 matrix percentage in dynamic one

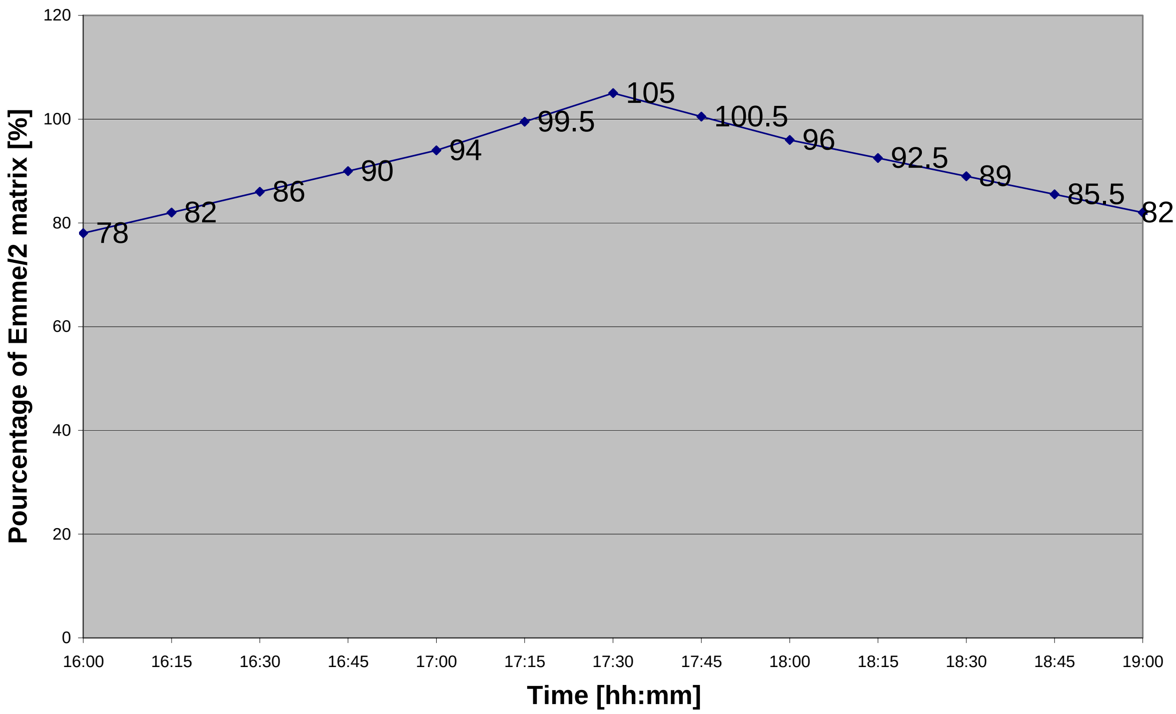


Figure 5 represents the percentage of the EMME/2 matrix uses for each 15 minutes. The input traffic grows between 16h00 and 17h30 and reduces after.

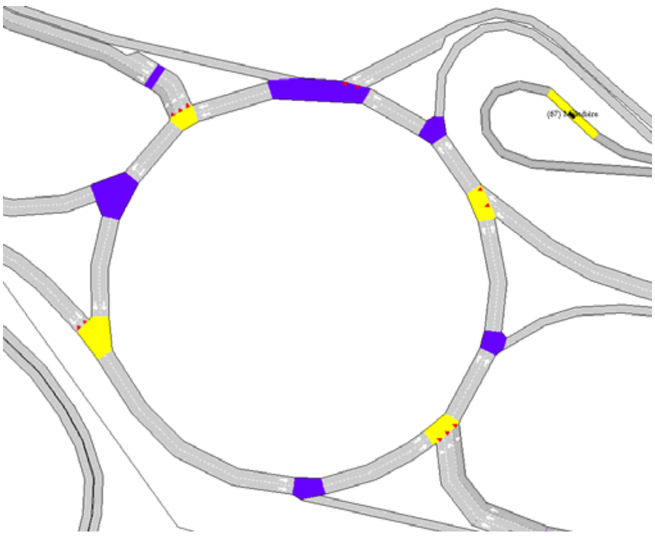
3. Network and behaviours parameters

The first group of parameters which have to be calibrated are linked with the network modelling and the car's behaviour. This kind of parameters can be global (the same for all the drivers or links), or local (only for one element). Using the first approach presents advantages: common settings are chosen for the whole network. However, in case of local problems, the second one is more suitable [3][4].

3.1 Network parameters

Network modelling can strongly influence the behaviour of the vehicles. In the case of several lanes roundabout (see Figure 6), for example, turns choice in junctions can change the input and output flow by a factor of 2. Modelling complex junction can lead to the same problems.

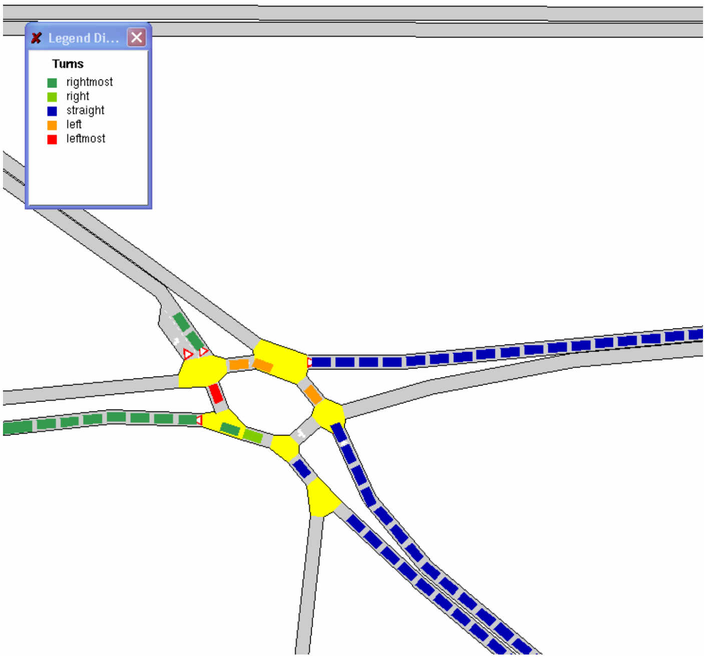
Figure 6 Roundabout modelling (Maladière)



To solve this kind of problems, only successive trials allow finding the best solution. Generally, the numbers of choice is not too high and different combinations could be tested in a short time. Some times, not representing all the complexity of a junction is preferable. This task has to be evaluated for each case.

Grid lock phenomena could occur in high density area (high connectivity). Grid lock is local lock of the network by cars which are disturbed by other cars, cars which turn around a roundabout or a block for example (see Figure 7).

Figure 7 Grid lock in a small roundabout during a simulation (Av. C.-F. Ramuz - Pully)



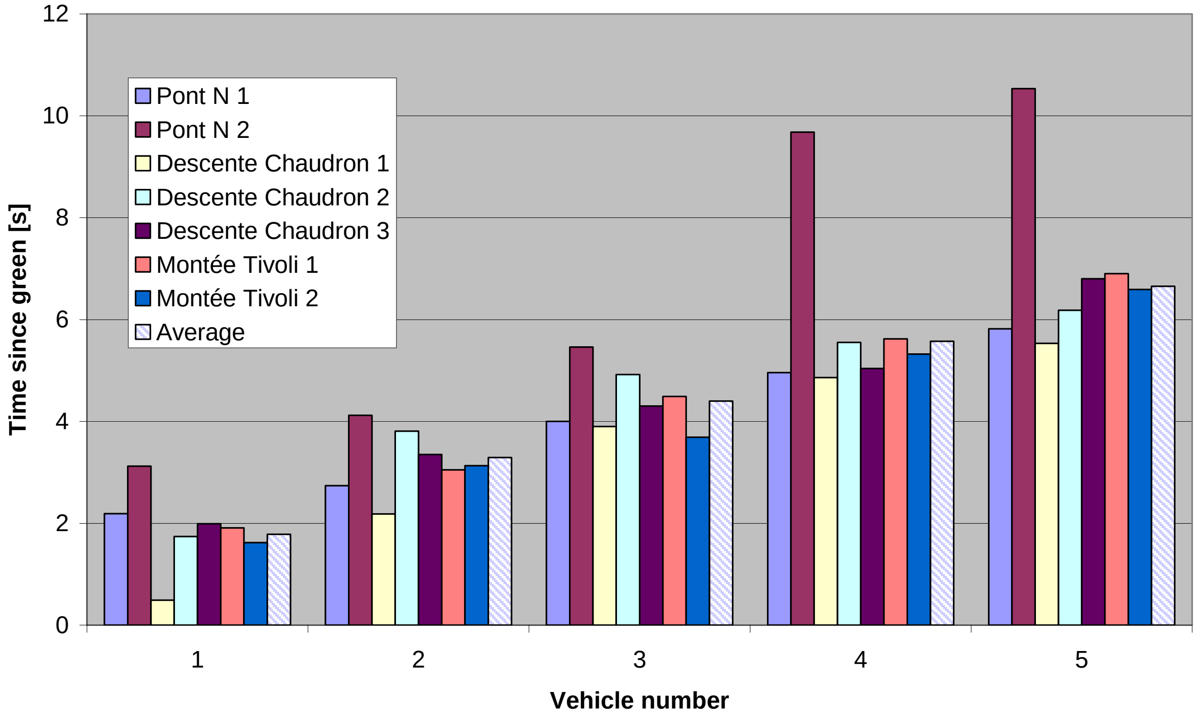
In this case, analysing the origin and the destination of the different vehicles implicated in the grid lock has to be done. Often, this phenomenon hides move global calibration problems, implied by the traffic assignment or route choice, but also may be due to a bad modelling of the junction.

3.2 Behaviours parameters

The parameter "reaction time at stop" defines the time taken by a stopped vehicle to react to the acceleration of the leader vehicle, or to a traffic light changing to green. This setting is used only in the case of starting vehicles. This parameter has a strong influence in the queue behaviour and consequently on the capacity of the junctions and paths.

To calibrate this parameter, field measurements have been done specifically for this research in the city. Some experimented results are regrouped in the Figure 8.

Figure 8 Reaction time at stop



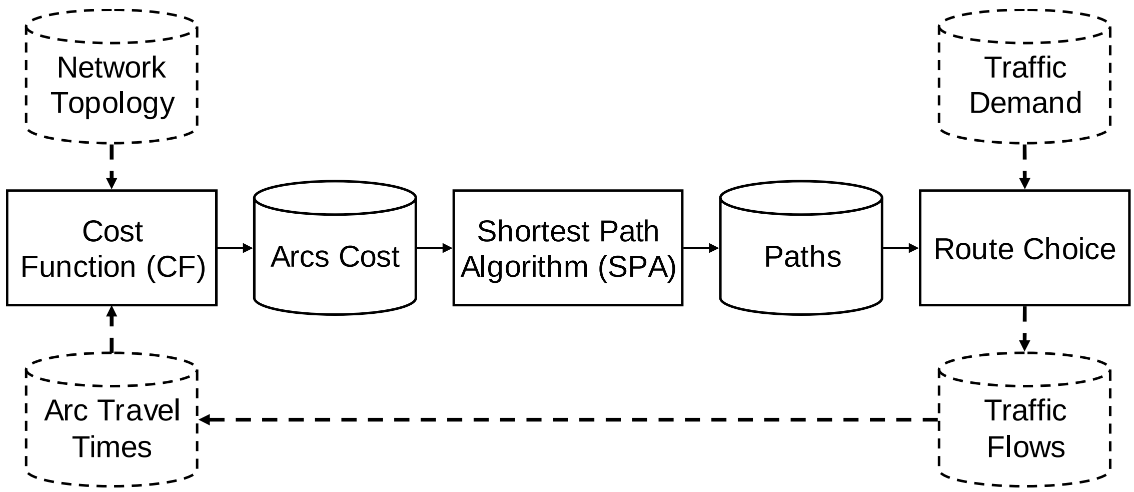
Reaction time at stop of the five first vehicles is represented. The time since the signal shift to green phase is measured. The hatching bar represents the average of the different measurements over each car. Several departures at traffic light have been analysed, in downhill, uphill and ground level configuration. This graph and car's behaviour in the network lead to the choice of 1.5 second as reaction time at stop. In AIMSUN, this parameter is global. It's therefore difficult to represent in all the situations the behaviour of the car at stop depending on the slope but this value is satisfactory according to the behaviour.

4. Traffic assignment

The main aim of traffic simulation, and particularly microsimulation, is to represent, the behaviour of the vehicle in the network, for the repartition on the network as well as for the route choice.

The Figure 9 represents the process of the Dynamic Traffic Assignment (DTA) in AIMSUN. Cost function and Route choice cases will be treated in this paper but not the Shortest Path Algorithm.

Figure 9 Dynamic Traffic Assignment process in AIMSUN



4.1 Cost Function

DTA is applied in microsimulation models as explained, for example, in [5] and [6]. 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.

The cost of the arc *a* at cycle τ $Cost_{a,\tau}$ is given by (1):

$$Cost_{a,\tau} = ALT_{a,\tau-1} \cdot [1+\varphi \cdot (1-\frac{Capacity_a}{Capacity_{max}})] \qquad (1)$$

Where:

$Capacity_{max}$ is the capacity of the most important arc in the hierarchy.

$Capacity_a$ is the capacity of the arc *a*.

φ is the capacity factor or weight, which has to be calibrated.

There are recurrent problems using this cost function, as presented in [7]. Simulated vehicles have a good knowledge of the traffic conditions, which in reality is not the case. Firstly, traffic assignment in the microsimulation model uses an actuated travel time in the link cost function. That does not represent the real knowledge of the drivers, which is rather based on a rough knowledge of the network from past experience. Secondly, the path calculation in the simulation model takes into account all the existing links of the network when, in reality, the drivers have only a limited knowledge of the network, mainly dependent on the hierarchal level of the links. Due to the differences between the knowledge of a real and simulated driver, the calibration has to deal with these facts in order to represent the traffic conditions in the best possible way.

In the case of large network, the difference between the information used to assign a route to a vehicle at its entrance time and the traffic conditions it will experience arriving at a sensible point situated faraway (in time) from the entrance can lead to a situation far from the equilibrium statements. To fix this problem and the too good knowledge of the network and the traffic conditions, microsimulators usually provide the possibility of rerouting the cars (guided cars) after a certain period, in order to take into account new traffic conditions. After several simulations, a percentage of guided vehicles have been determinate. Nevertheless, knowing the traffic conditions every time and every where is not satisfactory according of the reality. To avoid this problem, a certain percentage of car for each OD pair use the free flow path (path determined by the cost when cars can drive at maximum speed in the network). It represents the tourist, or occasional visitors who don't know the network well. These two percentages have to be determinate according to the reactivity of the drivers on the network. Finally, in our case, 40% of guided vehicles and 20 % of free flow path users have been chosen.

Another kind of current problem is the overuse of local streets. This phenomenon is linked with the too good knowledge of the link's network. Then, drivers can use all the surrounding path of the congestion. In real life, generally, daily users don't use local streets because of lack in their mental map network.

To improve the DTA and to complete the last remarks, road hierarchy have to be tuned. The structure formed by the different road type influences DTA. As seen before, link cost calculation is accorded to the travel time but also to the attractive effect of the road, the "comfort" (theoretical capacity). This hierarchy of the road type allows to modelling the preference of using the main streets of the network (free-ways, urban axes) instead of local streets. This parameterisation permits to control the overusing of small road too. This capacity structure increases the low capacity links turning cost. Different possibilities structures have to be compared to assess the consequences on the user's behaviour.

Table 10 gives an example of categories of road and its mains characteristics.

Table 10 Roads categories in Lausanne network

Road type	Max speed [km/h]	Capacity [« veh/h »]
Freeway	120	2000
Artérial	50	1990
Urban road	50	1700
Street	50	500
Zone 30 km/h	30	1
Alley	20	1

Figure 11 (screen shot) shows the network's hierarchy by colours. Freeways are in yellow, with higher capacity than principal roads (orange) and finally the secondary network road in green.

Figure 11 Network's hierarchy

More over, to avoid overuse of local streets, going down in the hierarchy during a path should be penalised. This is usually done to bypass a traffic jam, by using residential streets. Practically, this phenomenon can be detected by cars which leave an urban road to use a low capacity road. Then, by this penalisation, the modelling of the limited knowledge of the network and the low motivation of the users to leave the main street is better.

Capacity weight φ (Cf. cost function (1)) allows, with the same road hierarchy (structure), emphasizing or not the action of the attractive effect (theoretical capacity) in the cost function. Increasing this parameter will encourage drivers to use free-ways instead of small roads for example.

4.2 Route Choice

After calculation of the hypothetic paths between origin and destination by DTA, route choice allows different car affectation possibilities on these paths. Models determine the repartition of the traffic demand on chosen itineraries. The number of paths considerate is determinate by the user (number maximal of shorter path tree to keep). Logit and C-Logit models [8] are the most used; the second one is an extension of the first, but penalising overlapping situations.

For example, with C-Logit model, the probability P_k of using path k belong to the K_i tree of paths determined by DTA is: (2)

$$P_k = \frac{e^{\theta(V_k - CFA_k)}}{\sum_{j \in K_i} e^{\theta(V_j - CFA_j)}} \quad (2)$$

Where θ is the scale factor (which has to be calibrated), CFA, named "commonality factor" is proportional of the degree of overlapping of path k with other alternative paths. It is calculated as follows: (3)

$$CFA_k = \beta \cdot \ln \sum_{j \in K_i} \left(\frac{L_{jk}}{L_j^{1/2} \cdot L_k^{1/2}} \right)^{\gamma} \quad (3)$$

Where L_{jk} is the length of links common to paths j and k. β and α determinate the weight given to the "commonality factor". Experience fixes generally these parameters at 0.15 and 1.00, respectively.

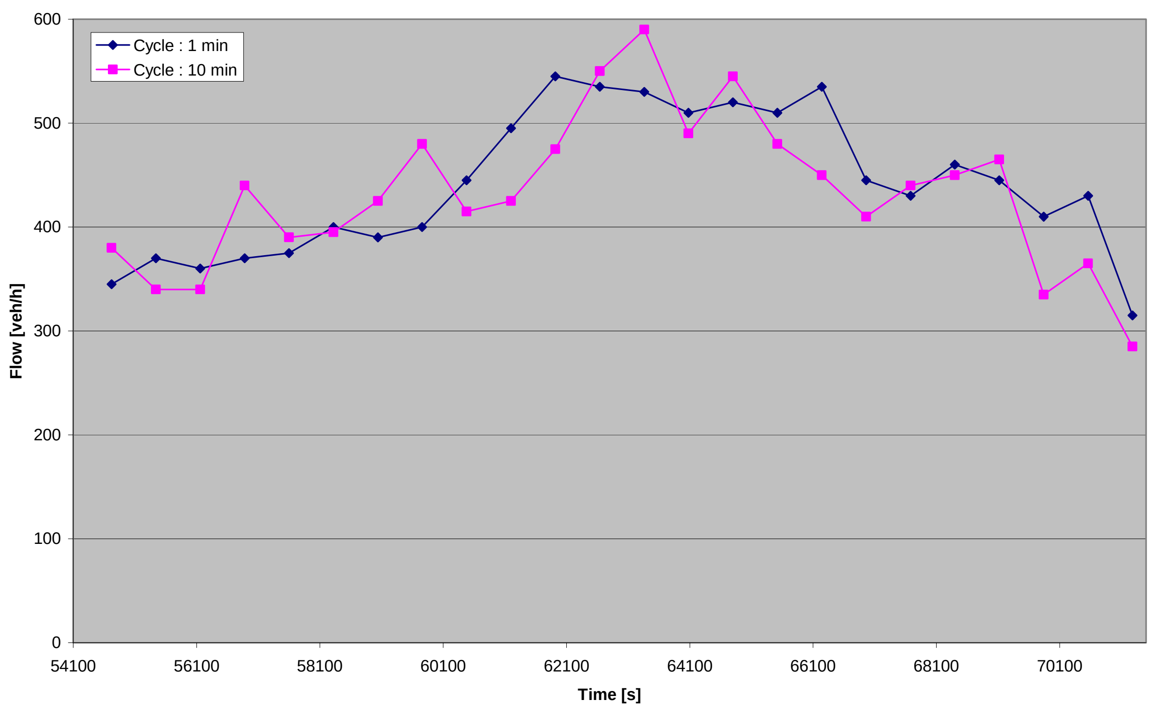
Determination of the route choice parameters has a big influence on the final result of the calibration. Firstly, route choice model has to be determinate according to the network configuration (proportional, binomial, Logit, C Logit, etc). In the case of a complex and large urban network, with a lot of different path possibilities from an origin to a destination, C-Logit model is usually preferred because of the commonality factor explained before. To control traffic distribution on the chosen itineraries, the determination of "number maximal of shorter path tree to keep" is essential. This parameter fixes the number of different paths route choice that will be used to distribute the demand. On one hand, lowering this value can lead to flip flop phenomena, (presented later), due to small number of possibilities. On the other hand, increasing this value will distribute traffic on a lot of different paths through the network and not representing the real demand repartition. Scale factor allows adaptation of the simulation model to the size of the network or more exactly to the car's travel time through the network. Average travel time in the network permits to calibrate this important route choice parameter. A particular attention has to be paid to the standard deviation of this average, if this value is too big, the model could be inappropriate due to the global aspect of the scale factor parameter.

Another important parameter, not directly visible in the cost function or the route choice, is the choice of the frequency of recalculation of the different link's cost. This value represents how often new alternatives routes are calculated. Thus, recalculation frequency allows providing a traffic information and evolution more or less actuated. So it has a strong relationship with the reaction time of the vehicles facing congestion situations. But, lowering the cycle (increasing the frequency) influences considerably the calculation time of the simulator.

Recalculation frequency added to cost function structure can lead to inconsistent situations, flip flop. This is a flow oscillation between several itineraries (usually two). This phenomena is due to the difference between the information used to assign a route to a vehicle at its entrance time and the one it will experience arriving at a sensible point situated faraway (in time) from the entrance (for non-guided vehicles). So the different possible paths are successively completely blocked by overload of traffic. Solution could be the adaptation of the cycle frequency or the percentage of guided vehicles to provide more accuracy traffic information and to smooth oscillations.

Figure 12 represents the traffic flow on a section with two different values for the cycle, the blue one with a calculation every minute and the pink every 10 minutes.

Figure 12 Traffic flow on section 1053 (cycle 1 and 10 min)



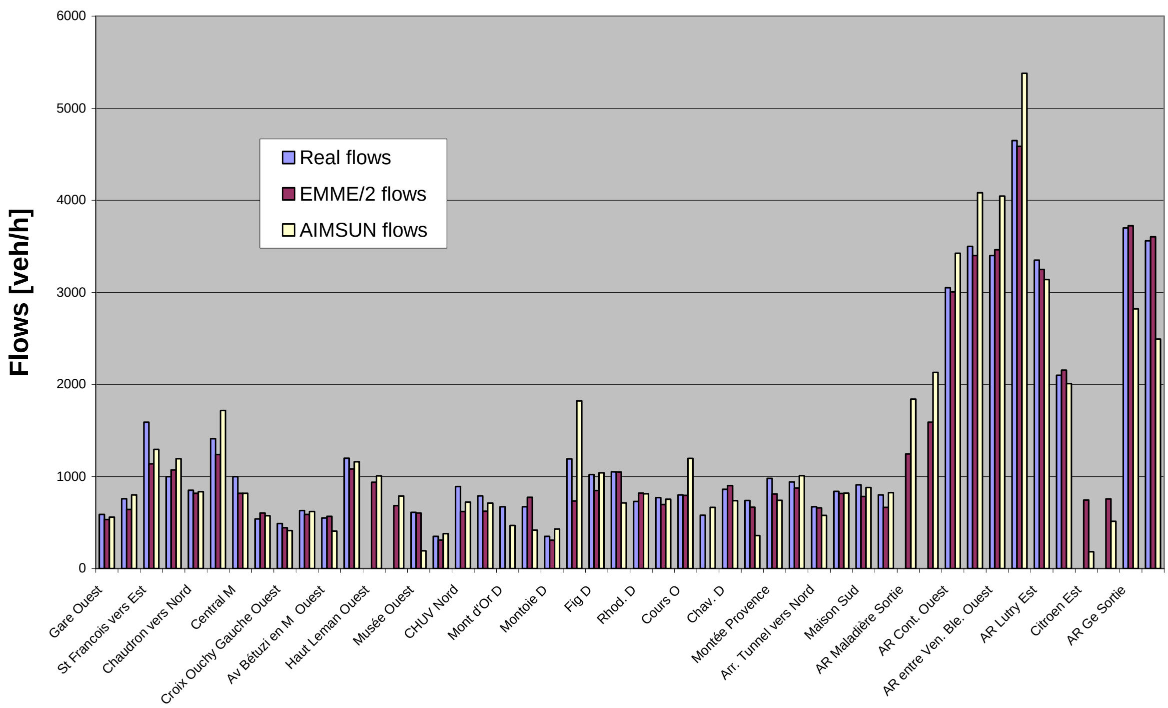
Blue line shows a normal load and unload of the traffic flow on this section. It follows the shape of the demand (see Figure 5). With 10 min cycle, the flow is very irregular. It characterise an oscillation between this section and another in an alternative path.

5. Some results

In this section, some graphic results obtained after the calibration of the Lausanne model are presented.

Figure 13 represents the comparison between 50 representatives comptings (by lane) spread out in the network (all road types are represented). Values shown are: AIMSUN simulation flows (yellow), results of EMME/2 calibration (red) and real compting (blue).

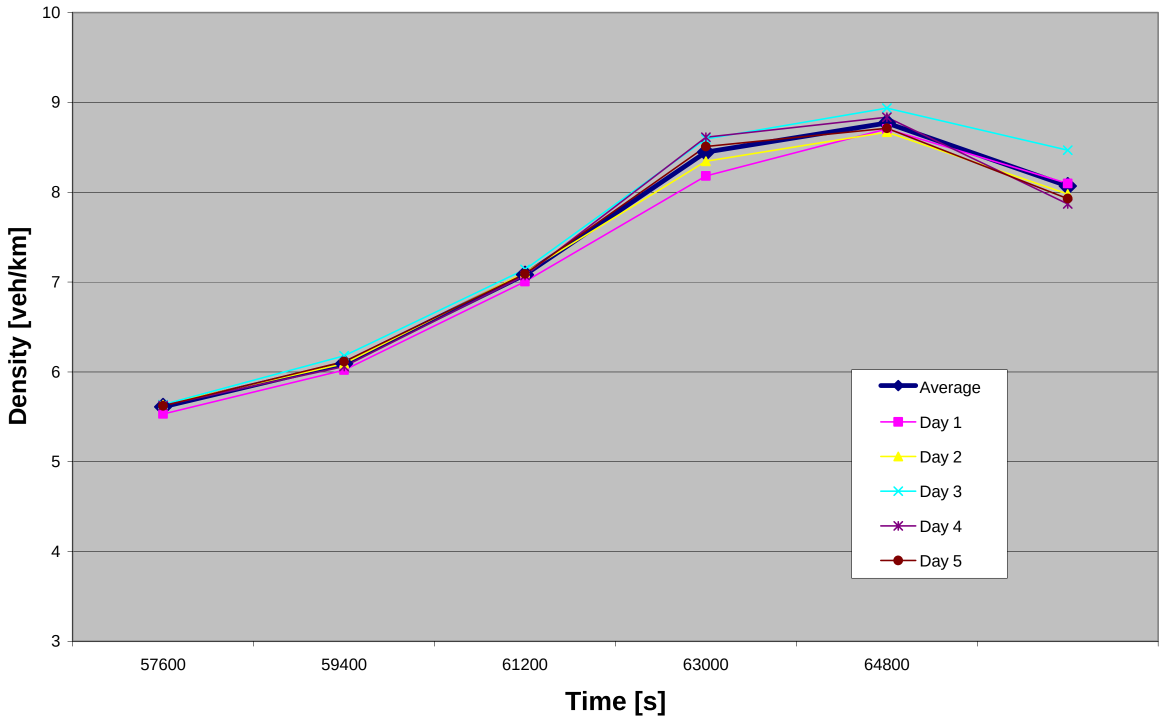
Figure 13 Flow comparison on 50 preventatives sections



As can be seen in Figure 13, for some points, AIMSUN flows are better than EMME/2 ones in comparison with real values. This can be explained by errors in the macroscopic simulator's calibration.

Figure 14 shows traffic density evolution (number of vehicles in the network), for five different seeds or days. The average is presented in dark blue.

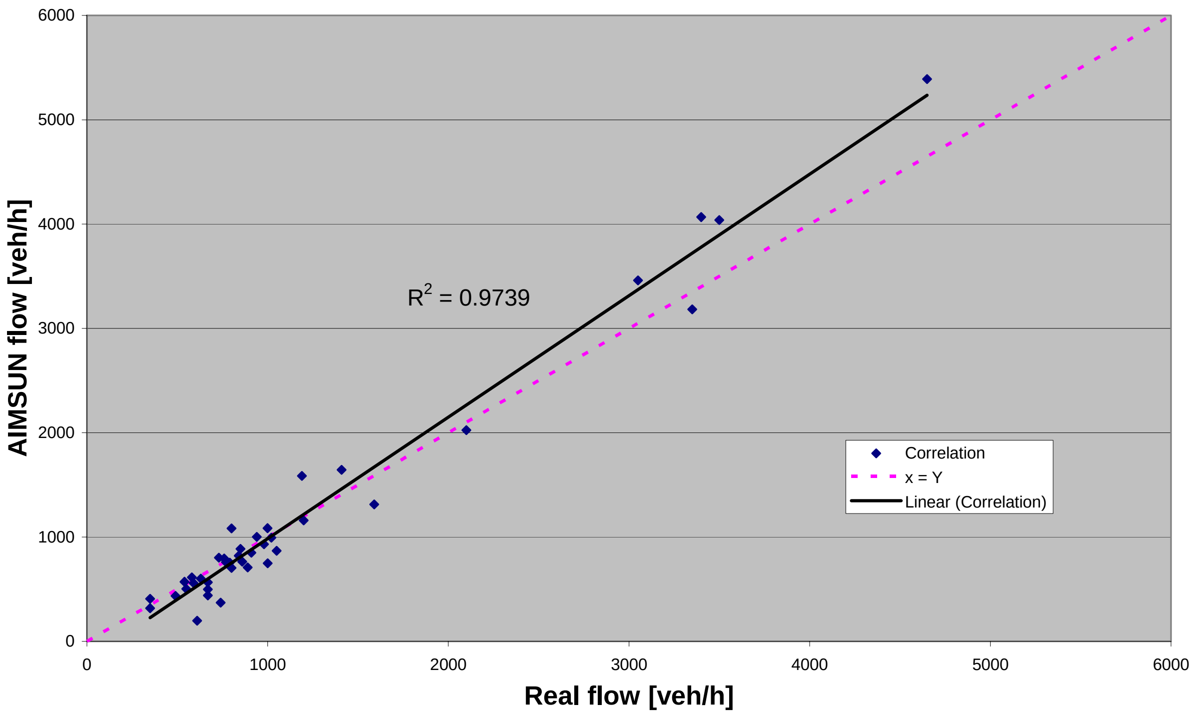
Figure 14 Network density evolution during the simulation



Density is the number of vehicle in the network divided by the total length of different sections. The daily difference is due to the stochastic behaviour of AIMSUN. The fine blue line (day 3) is a characterisation of a replication which was worse. It represents a particular difficult day for the traffic conditions. The charge and discharge are clearly represented by the network density curve. This curve follows the shape of the demand.

Figure 15 represents the correlation between flows from AIMSUN and real flows. AIMSUN flows are close to the real flows for the tested representatives sections. The correlation coefficient is quit satisfactory ($R^2 = 0.9739$).

Figure 15 Correlation between flows from AIMSUN and real flows



6. FURTHER RESEARCHES

The previously described remarks allow obtaining encouraging results. Nevertheless, more research has to be done to improve its efficiency and particularity it capacity of approximating satisfactorily real behaviours.

To improve non realist behaviours, as grid lock or blocked vehicles on predetermined path in spite of the impossibility to use it, a redirection or deleting process could be developed. This method should detect with accuracy if it's a modelling problem or a real behaviour before having an artificial effect on the simulation.

More, a deeper study of the different kind of driver has to be done on the base of [7] and [9]. This categorisation could allow getting better problems linked with AIMSUN's dynamic traffic assignment previously seen, particularly the too good knowledge of the network and the traffic conditions.

Finally, a similar study based on a large network but with a different structure (link density, flow, link length, etc.) could complete and improve previous remarks written on this paper.

7. CONCLUSIONS

Firstly, calibration is an indispensable task. Even if the simulator will give results without calibration, skipping this step would lead to unrealistic outputs. In the case of Lausanne, before the calibration some flows in the network were two or three times as much as real values.

Calibration is known to be the most difficult part of microsimulation project. Results are completely linked with the quality of this task. This is the weak spot of this kind of traffic simulator. There is a need for a particular attention to be paid to this process.

Although this study has been done on AIMSUN microsimulator, it is applicable on other microsimulator.

The different parameters which could be set in this simulator make calibration a difficult task.

Some problems can be solved by the network modelling, but, in most of the case, the difficulties come from the assignment of the cars on different possible paths through the network. In fact, this determination, in order to represent the human behaviour, is the most difficult part of the calibration and it's also the process which allows the most possibilities.

As discussed in this paper, in lots of cases, a specific study is necessary to find the best way to model the real situation. This study is an approach to the problem.

This process gives general solution for classical or recurrent problems, but in most of the cases, a particular consideration must be done.

Finally, calibration must be done by a person who has a good control of the simulator, of course, but who should know the network's behaviour in reality too.

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