COMBINING MACROSCOPIC AND MICROSCOPIC APPROACHES FOR TRANSPORTATION PLANNING AND DESIGN OF ROAD NETWORKS

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ABSTRACT

Traffic assignment models based on the user equilibrium approach are one of the most widely used tools in transportation planning analysis. Based on Wardrop's, principle as a behavioral principle modeling the route choice process, they lead to a nice mathematical model for which there are efficient algorithms that provide solutions in terms of the expected flows on network links. Resulting flows offer a static average view of the expected use of the road infrastructure under the modeling hypothesis. This information has usually been enough for the planning decisions. However, the evolution of advanced technologies and their application to modern traffic management systems require in most cases a dynamic view complementing the static estimates provided by the assignment tools. The planned infrastructure is probably sufficient for average demand, but time-varying traffic flows, i.e. at peak periods, combined with the influence of road geometry, can produce undesired congestion that can not be forecasted or analysed with the static tools. There is a clear case for a change in the analysis methodology such as combination of a well known traffic assignment tool, the EMME/2 model, with a microscopic traffic simulator, the AIMSUN2 (**A**dvanced **I**nteractive **M**icroscopic **S**imulator for **U**rban and **N**on-urban **N**etworks) which this paper proposes.

INTRODUCTION

Traffic assignment models based on the user equilibrium approach are one of the most widely used tools in transportation planning analysis. All the modeling hypotheses lead to a nice mathematical model for which there are efficient algorithms that provide solutions in terms of the expected flows on network links. Modeled flows offer a static average view of the expected use of the road infrastructure under the modeling hypothesis. This information has usually been sufficient for planning decisions.

However, the evolution of advanced technologies and their application to modern traffic management systems require in most cases a dynamic view complementing the static estimates provided by the assignment tools. The planned infrastructure is probably sufficient for average demand, but time-varying traffic flows, i.e. at peak periods, combined with the influence of road geometry, can produce undesired congestion that can not be forecasted or analysed with the static tools. There is a clear case for changing in the analysis methodology. This paper proposes of the combination of a well-known traffic assignment tool, the EMME/2 model, with a microscopic traffic simulator, the AIMSUN2 (**A**dvanced **I**nteractive **M**icroscopic **S**imulator For **U**rban And **N**on-Urban **N**etworks).

There is another type of situation in a dialogue between a microscopic and a macroscopic approach may be desirable. Microscopic simulation can admit two types of input; the more classical one model traffic flows at model-input sections and turning proportions at the intersections. Current trends in microscopic modeling allow the input to be defined in terms of a time-sliced origin-destination matrix. Time-sliced origin-destination matrices are usually very difficult to obtain and quite often analysts must resort to heuristic procedures to adjust matrices and use measured flows for different time intervals. Most of these adjustment procedures are based on bi-level optimization approaches that solve a traffic assignment problem at an intermediate stage. The outcome of the adjustment procedure becomes the input to the microscopic model. A direct communication between the two systems makes the input task easier and error-free.

The methodology proposed in this paper can be summarized as follows: starting from the graphic user interface GETRAM (**G**eneric **E**nvironment for **T**raffic **A**nalysis and **M**odeling) and utilizing a set of graphic editors working on the network representation provided by a GIS, a microsimulation model is built of the road network under study. This network representation is then transferred into the network representation used by the assignment model, the EMME/2 in our case. The transfer ensures the consistency of both representations, and a one-to-one correspondence between the centroids used in the assignment to model the demand matrix and the centroids used in the microscopic model for the same purpose. This consistency enables the exchange of information between the two models. The logic of the proposed methodology is illustrated in **Figure 1**.

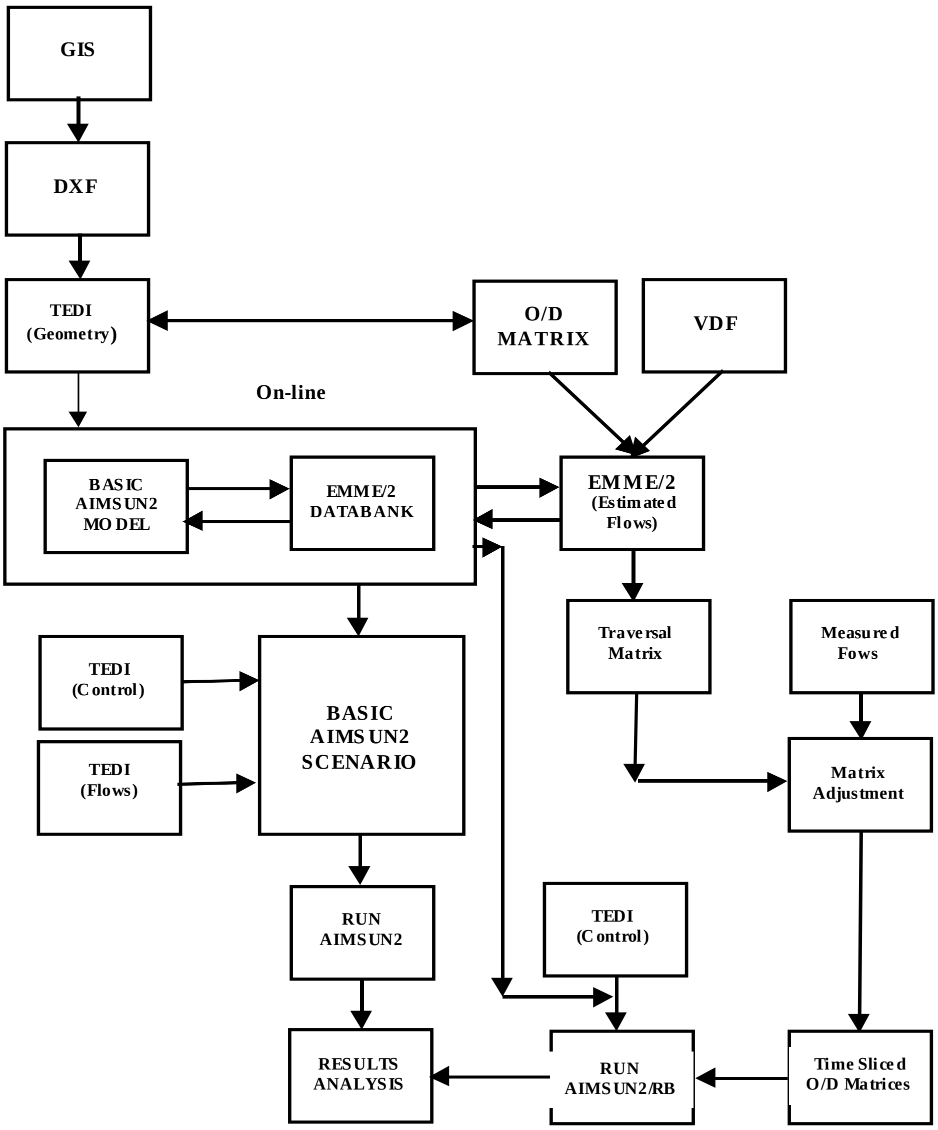


Figure 1. Flow Diagram of the Methodology

This methodology is illustrated in the paper with a real life project: a study done for the Spanish company APIA XXI to compare two alternative geometric designs of a motorway in Barcelona, with complex exchange nodes with other motorways.

First, this paper briefly describes the GETRAM environment and AIMSUN2 simulator; then, discusses in detail macroscopic-microscopic integration through GETRAM, including what has already been put into practice. The combined macro-micro analysis methodology is then applied to a case study. It ends with Conclusions and References.

GETRAM ENVIRONMENT

GETRAM (**G**eneric **E**nvironment for **T**raffic **A**nalysis and **M**odeling) (Grau & Barceló, 1993; Grau, 1994) consists of a user-friendly graphical interface, a traffic network graphical editor (called TEDI) supporting any kind of road network geometry, urban or interurban, a network database and a module for storing and presenting results, including the possibility of an animated simulation output. A set of high-level, object-based application programming functions (API) provides the support for integrating a new model into the environment, accessing any kinds of data and manipulating objects in the network representation. Recently, GETRAM has incorporated the models AIMSUN2 and EMME/2. **Figure 2** displays schematically the conceptual approach to this software architecture. The system has fully open software architecture, in the sense that traffic control models, vehicle behavior models, route calculation and route choice models, among others, are independent of the simulation logic and therefore can easily be exchanged for alternative models.

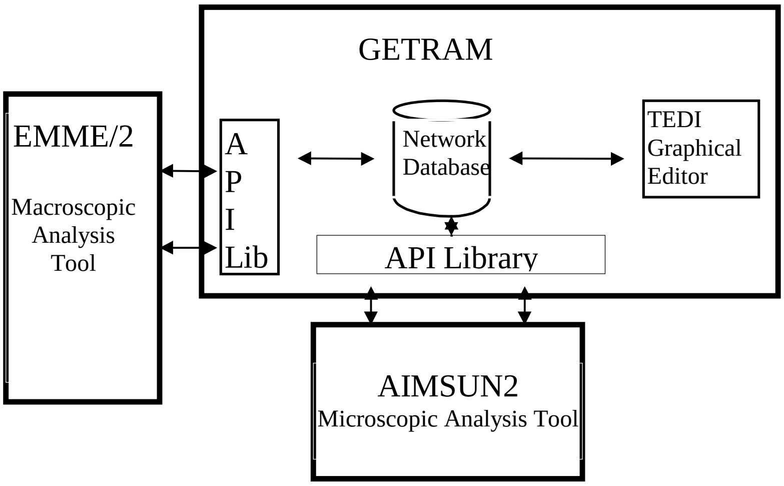


Figure 2. GETRAM Conceptual Diagram: Integration of Macroscopic and Microscopic Analysis Tools

AIMSUN2 (Ferrer & Barceló, 1994) is a microscopic simulator integrated into GETRAM and capable of reproducing the real traffic conditions on an urban network that contains both expressways and arterial routes. It provides a very detailed modeling of the traffic network since it distinguishes between different types of vehicles and drivers, and deals with a wide range of network geometries, incidents, etc.

The output provided by AIMSUN2 includes a continuous animated graphical representation of the traffic network performance, a printout of statistical data (flows, speeds, journey times, delays, stops) and data gathered by the simulated detectors (counts, occupancy, speeds, queue lengths). **Figure 3** is included for comparison purposes, between a typical EMME/2 assignment output and an AIMSUN2 simulation.

The input required by AIMSUN2 is composed of three types of data: network description, traffic control plans and traffic conditions. The network description contains information about the geometry of the network, turning movements, layout of links (or sections) and junctions, and location of detectors along the network. The traffic control plans are composed of the description of stages and their durations for signal controlled junctions, the priority definition for unsignalized junctions, and any required ramp-metering information. AIMSUN2 accepts two classes of input for the simulation, depending on how traffic conditions are going to be simulated.

AIMSUN2 models traffic network as a set of sections (links) connected to each other through nodes. The basic modeling structure is the Entity: sections are composed of section entities which correspond to lanes, and nodes are made up of node entities which connect input and output entities and define the turning movement. Vehicles move along the network through entities according to driver behavior models, which are a function of their state, defined by the current and adjacent entities.

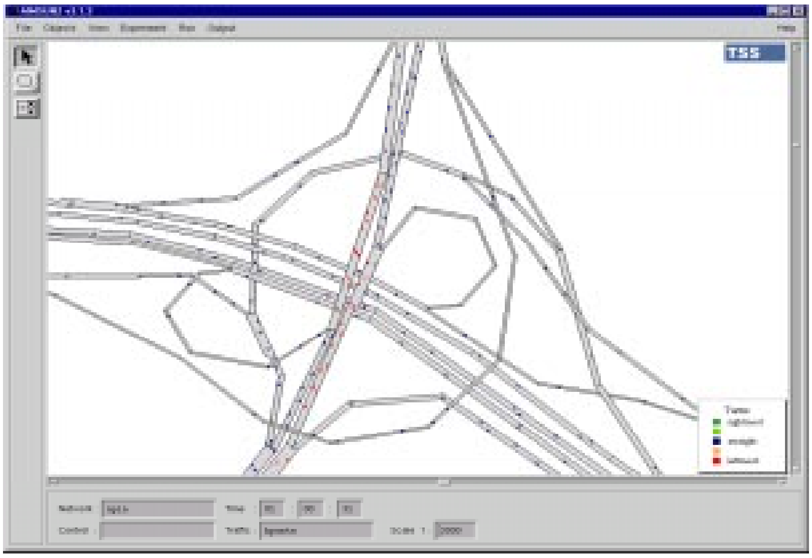
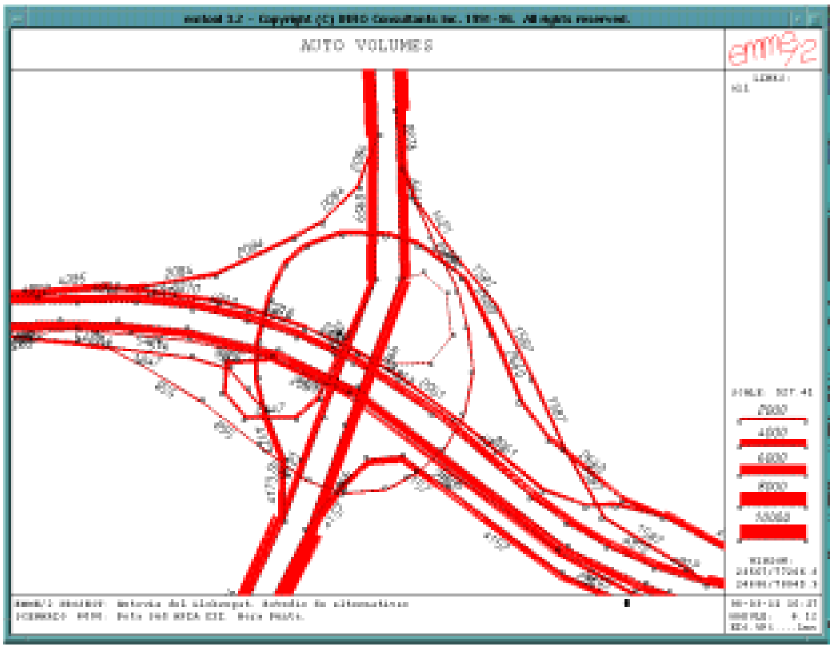


Figure 3. AIMSUN2 simulation vs. EMME/2 Assignment: Llobregat Ring-road in one of the scenarios.



An entity link, or section, is defined by a set of attributes whose values are specified through a dialogue window with five fields: Basics, Detectors, Metering, VMS and Reserved. The Basics group of attributes concerns the section type (several possibilities), maximum speed (speed limit in the section), capacity, altitude (slope of the section) and a user attribute.

The traffic conditions may be input in two ways: as time-sliced O/D matrices in EMME/2 Batch Entry format, or as the turning proportions at junctions plus the input distribution of vehicles. It depends on the selected input mode how vehicles are generated and input into the network during the simulation process: either at the input section following a random generation model based on the mean input flows for that section (a negative exponential or shifted negative exponential or a platoon distribution), or at their specific origins. In the first case, they are distributed randomly on the network according to the turning proportions defined for each junction of the network, which means that vehicles do not know their complete path along the network, but only their next turning movement. In the second case, vehicles are allocated to specific routes from their origins to their destinations. In this case explicit routes are computed, according to various model alternatives, such as time-dependent shortest paths, according to vehicle origins and destinations, and vehicles are allocated to the routes following specific route choice models. Drivers tend to travel at the speed they want in each section, but within certain objective conditions by their state (preceding and adjacent vehicles, traffic lights, etc.).

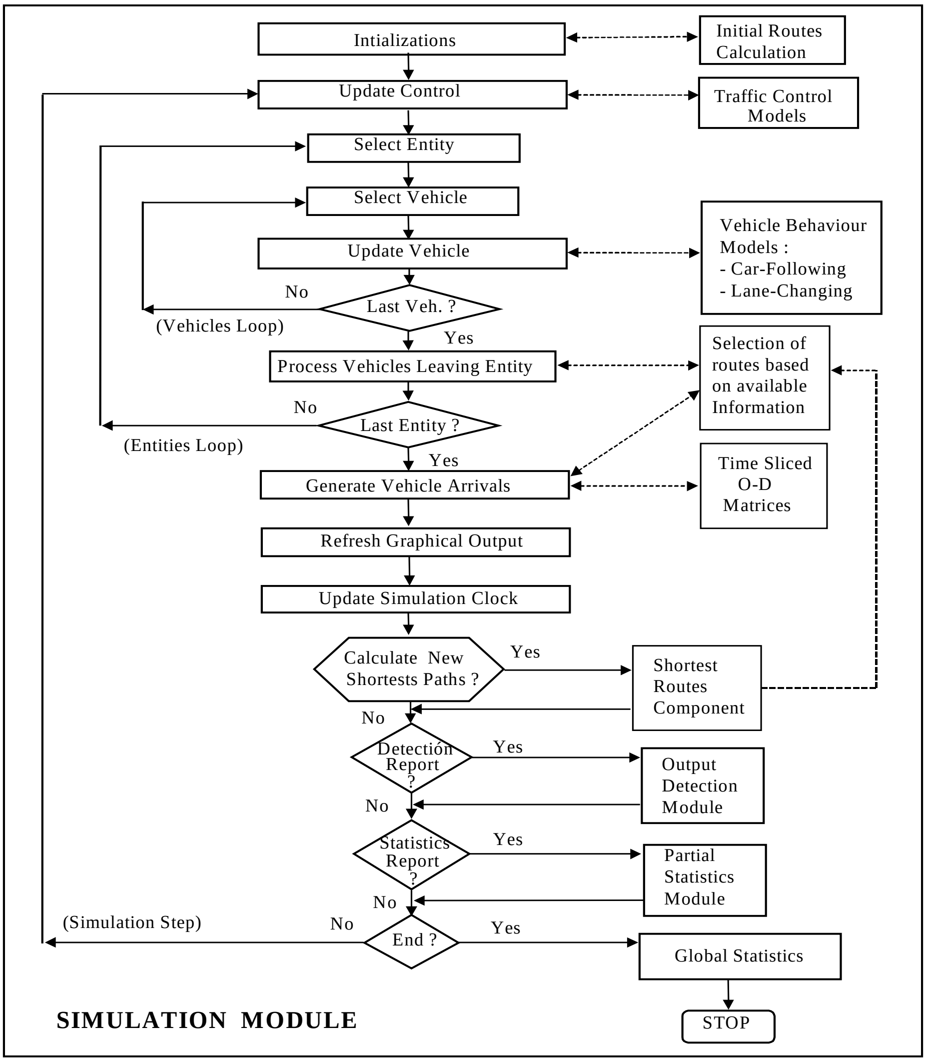


Figure 4. AIMSUN2 Simulation Process

AIMSUN2 includes various types of traffic control: traffic lights, rights of way and ramp meterings. A stage-based approach is considered for Traffic Light Control. Unsignalized junctions are represented as signalized junctions with only one stage, in which all movements have right of way and a definition of priorities between conflicting manoeuvres has to be provided. To model give-way junctions a Gap Acceptance model is included which accounts for higher-priority vehicles, the distance of vehicles from their hypothetical collision points, their speeds, and their acceleration rates in order to determine the time needed by the vehicles to clear the junction. With this information, a decision to cross or not as a function of the level of risk of each vehicle (driver) can be taken.

The simulation process in AIMSUN2 is detailed in **Figure 4**. One can see three loops in the process: per simulation step, per entities and per vehicles in entities reflecting the object-oriented design. In the right hand side of the figure, models are referenced in the stages of the process, in a fully modular design that allows the interchange of such modules to fulfill the customization to user-implemented modules.

MACROSCOPIC-MICROSCOPIC MODEL INTEGRATION IN GETRAM

From digitalized cartography representing the area of study, in .dxf format, the graphical editor TEDI allows the user to define network links, nodes, centroids, turning movements and traffic control, through dialogue windows. Once the network, traffic control and traffic conditions are defined in TEDI, there are several interfaces that can be activated in the GETRAM environment:

- GETRAM to EMME/2.
- GETRAM to AIMSUN2.
- EMME/2 to AIMSUN2 via GETRAM (partially developed).

GETRAM to EMME/2

This interface generates a compatible EMME/2 network and turning movement description. An EMME/2 network consists of modes, nodes and links (which constitute the base network), turns, transit vehicles, transit lines and transit segments. These components of the network have three types of attributes: standard attributes, extra attributes (user-defined and not considered in the current version of the interface) and assignment results. A proper EMME/2 Databank for performing the loading operation of the former two files must satisfy the following:

- GETRAM and EMME/2 must have compatible units for lengths and
- Transport modes in EMME/2 have to be defined in the same way in GETRAM
- Transit vehicles must be loaded. The description of transit lines is not included in the current version of the interface or in the GETRAM Network Database. Since some studies might require transit modeling, a basic set of transit modes is assumed and a default vehicle table containing the definition of the transit vehicle types is proposed.
- Volume delay and penalty functions must be loaded. Only auto volume-delay functions for auto times on links on the auto network (in minutes) and turn penalty functions for auto times on turns at intersection nodes (in minutes) are included in current version of the GETRAM to EMME/2..
- The destination scenario must be created unprotected against modifications. Node, link and turning movement tables have to be initialized.

The Base Network Batch Entry file generated by GETRAM comprises:

- Node description: node identifiers, coordinates and labels. Centroids are defined before regular nodes and their identifiers are smaller than any regular node identifier.
- Link description: each record defines a directional link whose origin and destination node are previously defined in the node description section. Each record contains: origin node, destination node, list of modes allowed on the link, link type (`type`), number of lanes, volume-delay function (`vdf`) set to 1, user link fields 1 to 2 set to 0 and user link field 3 containing the `section id`. in GETRAM Network Database.

- A `t nodes init` and `t links init` records are included in the correct position of the Batch Entry file. Destination scenario in EMME/2 Databank must be created and empty, without any nodes and links.

In the current version of this interface, EMME/2 attribute `vdf` is set to 1, and a self-developed EMME/2 macro assigns `link` capacities and `vdf` codes according to link `type` and number of `lanes`. Link capacities are held by user link field 1 (`ul1`) after EMME/2 setting macro execution. Penalty codes for turning movements are assigned according to maximum turning speed value defined by TEDI. Turn penalty functions assigned by the interface according to the maximum speed (`v_max`). The main link types included in the interface are: connector, motorway, road, urban road, arterial, signalized street and unsignalized street. In most cases, several vdf functions are allowed for each of these main types, depending on the maximum speed, number of lanes and lane capacity. Currently, there are thirty link types and 18 different vdf functions. The file containing link types available for a given application is a user file that can be customized as necessary: for each type, an identifier, the maximum speed allowed and the lane capacity must be defined. The EMME/2 setting macro should be adapted to be compatible with the GETRAM/TEDI link type definition.

The Turning Batch Entry file created by GETRAM contains a list of records, each of which contains: At node, From node, To node and a turn penalty function identifier. The code for banned movements is *0* and for non-penalized turnings is *-1*.

One of the most complicated aspects of the conversion process at the interface is the transfer of the centroid-connector structure. There are two ways of transferring GETRAM connector structure to EMME/2:

- Identical one by one. This is the default option.
- Using the so-called *total equivalent centroid option*, that performs the transfer depicted in **Figure 5** for a centroid *n*. Equivalent centroids can be used subsequently in the EMME/2 traffic model, in which total generations and/or attractions for a zone or centroid can be used as a traffic count. In the figure, centroid n is connected to the network using an auxiliary regular node m. The interface automatically bans turning *movements* $i \to m \to j,\ \ i \to m \to k,$ ... and so on and only movements $i \to m \to n,\ \ n \to m \to j,\ \ n \to m \to k$ *and* $n \to m \to l$ are allowed.

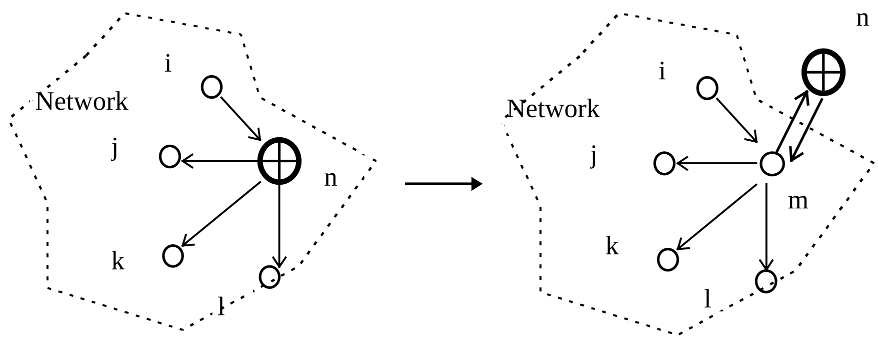


Figure 5. GETRAM to EMME/2 interface: total equivalent centroid-connectors transfer

GETRAM to AIMSUN2

From its network database, GETRAM generates a compatible AIMSUN2 network with traffic control and traffic conditions defined as available or requested by the user. The AIMSUN2 simulator is fully integrated into the GETRAM environment, and so the user does not have to worry about with the input simulation data files: the natural way of preparing and starting a simulation is from the GETRAM environment, as shown in **Figure 6**.

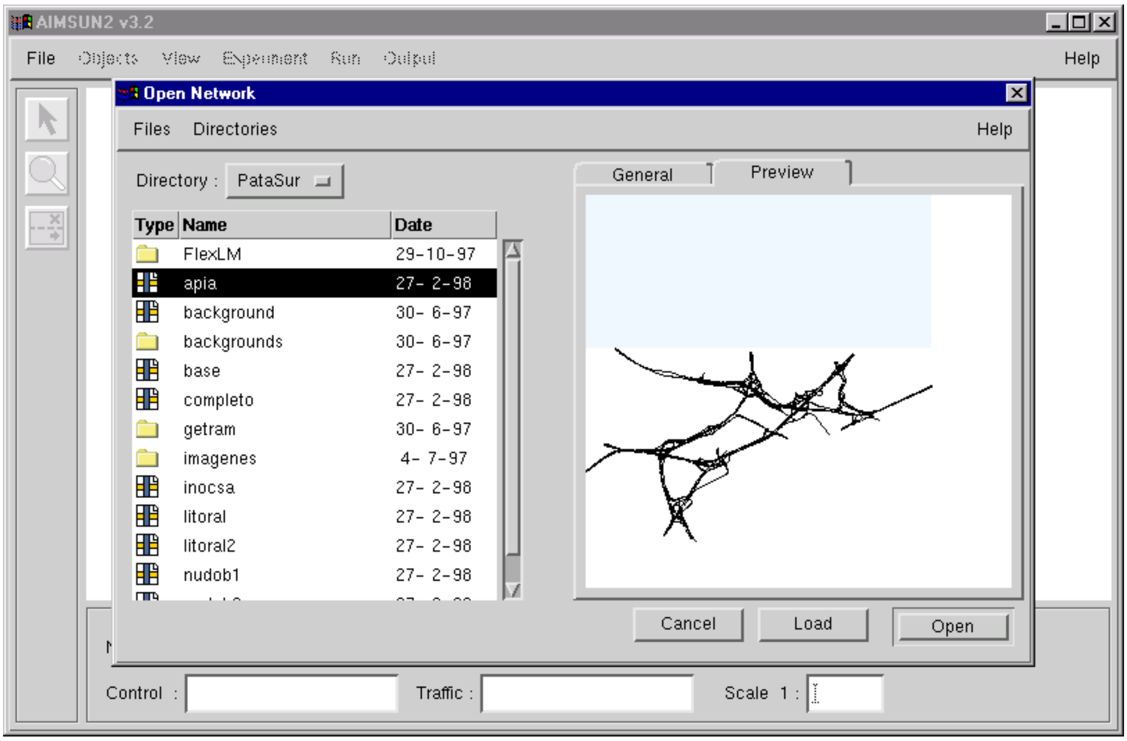


Figure 6. GETRAM: Starting an AIMSUN2 simulation

EMME/2 to AIMSUN2 via GETRAM

It offers several possibilities that are fully integrated into *GETRAM Menu options*:

- To define turning proportions and average input vehicle rates to be included as traffic conditions in a microscopic simulation in AIMSUN2. A C program takes as input: a report of assigned auto volumes from EMME/2 (`volau`) and a *batchout EMME/2 ASCII file* generated by a user macro containing the corresponding turning flows. These two files are processed to obtain a traffic conditions file in AIMSUN2 simulator format.

- If the only O/D matrix available is obsolete, but some traffic counts can be gathered from at least 10% of EMME/2 links, well-distributed, spatially and in link types, the matrix-updating macro (`demadj.mac`) in EMME/2 can be used to get a current matrix for microscopic simulation in AIMSUN2 as an O/D matrix or set of time-slices O/D matrices (defined by the user). To include a EMME/2 batchout file for O/D matrix description in GETRAM (to be used in AIMSUN2), the name of the batchout file (one per matrix), the relevant time interval and vehicle modality have to be specified by a specific dialogue
- Using EMME/2 transversal matrix computation and equilibrium assignment procedures to define traffic conditions for a given sub-area that requires a detailed study by simulation. This option is not yet fully automatic.

CASE STUDY

In the River Llobregat valley to the South of the Metropolitan Area of Barcelona (Spain) a new motorway is being built. This area is one of the most active industrialised in Spain. Some existent infrastructure, such as the Llobregat and Bellvitge ring-roads, will be adapted for this new Llobregat Motorway (*Autovia del Llobregat*). In addition, a new by-pass between the urban area and the south coast access road (called the *South Leg*) will be incorporated to the road network.

Five infrastructure elements, either alone or together, are included in this case study: Llobregat Motorway, South Leg Proposal 1, South Leg Proposal 2, Sant Boi Ring-road Modification and Bellvitge Ring-road Modification.

The objectives of the study were to assess several alternative options (`scenarios`). The study follows the classical four-step methodology, but breaks new ground with respect to the computer tools used for model building and assessment, which combine macroscopic models, through the static traffic assignment facilities of EMME/2, with the microscopic simulation facilities of AIMSUN2. Both were integrated into the GETRAM environment.

AIMSUN2 and compatible EMME/2 models were built according to the proposed methodology as described in section 3. The characteristics of some of the scenarios developed, the Base scenario and the South Leg proposals (the ones for which a microscopic simulation analysis was requested) are depicted in **Figure 7**

```
------------------------------ Scenario  2001 -------------------------------

Scen 2001(D-- A-): Autovia Llobregat.Base Scenario PP.
Network size:          3 modes                      0 transit vehicle types
                     106 centroids                  0 transit lines
                     2962 regular nodes             0 transit line segments
                     3759 directional links         8092 turn table entries

Fixed demand auto assignment:       97-02-12 13:49
Demand:                      mf04: UPC_PP   ADJUSTED DEMAND
Stopping criteria:           iter=   70     rgap=  0.50%     ngap=  0.50
Number of iterations:        70      stopped by: iter

------------------------------ Scenario  5000 ------------------------------

Scen 5000(D-- A-): SOUTH LEG PROPOSAL 1: INOCSA. PP.
Network size:           3 modes                     0 transit vehicle types
                     106 centroids                  0 transit lines
                     3022 regular nodes             0 transit line segments
                     3845 directional links         8183 turn table entries

Fixed demand auto assignment:       97-02-18 16:21
Demand:                      mf04: UPC_PP   ADJUSTED DEMAND
Stopping criteria:           iter=   70     rgap=  0.50%     ngap=  0.50
Number of iterations:        70      stopped by: iter

------------------------------ Scenario  6000 ------------------------------

Scen 6000(D-- A-): SOUTH LEG PROPOSAL 2: APIA-XXI. PP.
Network size:           3 modes                     0 transit vehicle types
                     106 centroids                  0 transit lines
                     3063 regular nodes             0 transit line segments
                     3899 directional links        8178 turn table entries

Fixed demand auto assignment:       97-06-16 11:02
Demand:                      mf04: UPC_PP   ADJUSTED DEMAND
Stopping criteria:           iter=   70     rgap=  0.50%     ngap=  0.50
Number of iterations:        70      stopped by: iter
```

Figure 7. GETRAM: EMME/2-AIMSUN2 Scenario characteristics: Base and South Leg proposals

The most recent mobility information available for the whole study area dated from 1991, in the so-called EMO’91. It contained the full set of compulsory home-based trips for the population of Catalonia. The EMO’91 modal matrices were easily adapted to the zonification of the current study, since EMO’91 zonification is detailed and only requires a simple aggregation phase for conversion.

An exhaustive plan of traffic counts was designed, so that there would be sufficient traffic data to update the obsolete O/D matrices mandatory trips, covering cars and trucks, for the daily and the peak morning period (from 6 to 9 a.m.). This updating would reflect full private mobility and use EMME/2 auxiliary macro `demadj.mac` for matrix adjustment (Spiess, 1990). EMME/2 software enables current O/D mobility matrices to be calculated and several scenarios to be evaluated. Table 1 shows the total number of trips, after adjustment from traffic counts, for a day and a peak period, for the whole area and for the sub-area selected for microscopic simulation analysis. The microscopic simulation sub-area contains 977 links in the Base scenario; around 100 traffic counts are available for each time period (daily and peak periods). For the whole area, around 250 traffic counts were available: the linear regression model between observed and EMME/2 predicted volumes has a determination coefficient greater than 0.9 and the scatter-plot of observed *vs.* predicted volumes is depicted in **Figure 8**.

Table 1. EMME/2: O/D totals after adjustment because of traffic counts

OD TOTALS	*DAILY PERIOD*	*PEAK PERIOD*
WHOLE AREA	868 000	161 000
MICROSCOPIC SIMULATION AREA	407 000	71 000

The total number of scenarios developed with GETRAM for EMME/2 model is 10. The most conflictive sub-areas are the Llobregat and Bellvitge ring-roads and the South Leg connection to the airport. In order to correct the designs of these critical ring-roads to prevent congestion black spots in peak morning scenarios and improve the level of service, microscopic simulation with AIMSUN2 was run. Two peak morning scenarios modeling Proposal 1 and Proposal 2 for the Llobregat ring-road were studied in detail and evaluated in terms of average speed, average occupancy and queue lengths.

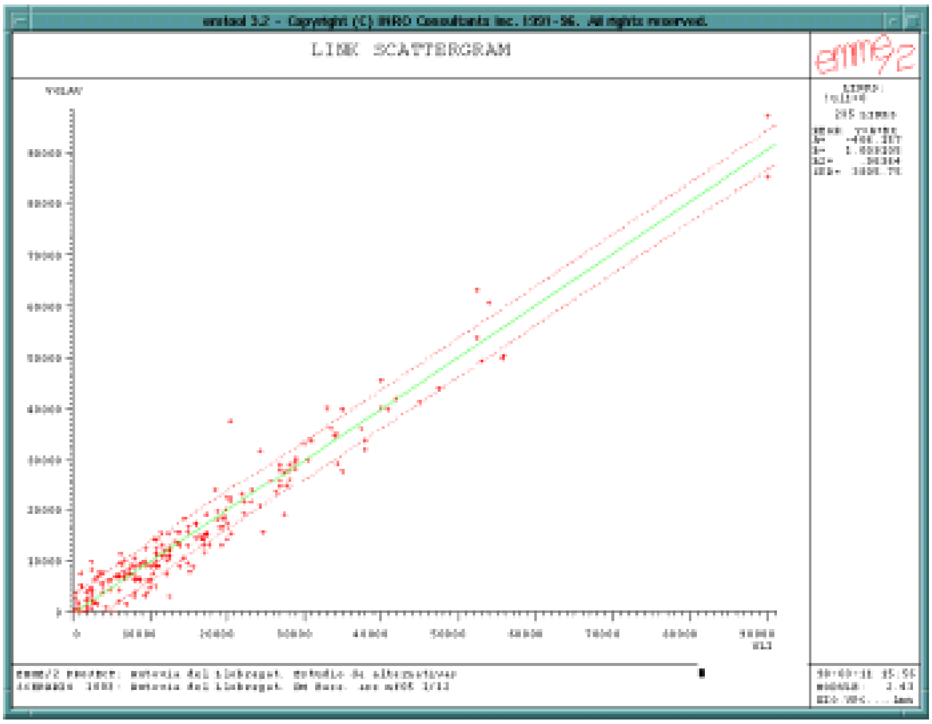


Figure 8. EMME/2: Observed versus predicted volumes after adjustment. Daily period

The results macroscopic assignment provided by EMME/2 on the Base and South Leg proposal scenarios in the microscopic simulation sub-area are summarized in table 2

Table 2. EMME/2 results. Base and South Leg proposal scenarios: microscopic simulation area

EMME/2	*MICRO AREA*	*DAILY PERIOD*		*PEAK PERIOD*	
SCENARIOS	**Links**	**Speed (km/h)**	**Occupancy**	**Speed (km/h)**	**Occupancy**
BASE	*977*	*54.65*	*0.316*	*42.29*	*0.484*
S.L. Proposal 1	*1 061*	*62.30*	*0.233*	*49.00*	*0.393*
S.L. Proposal 2	*1 115*	*60.06*	*0.231*	*48.78*	*0.396*

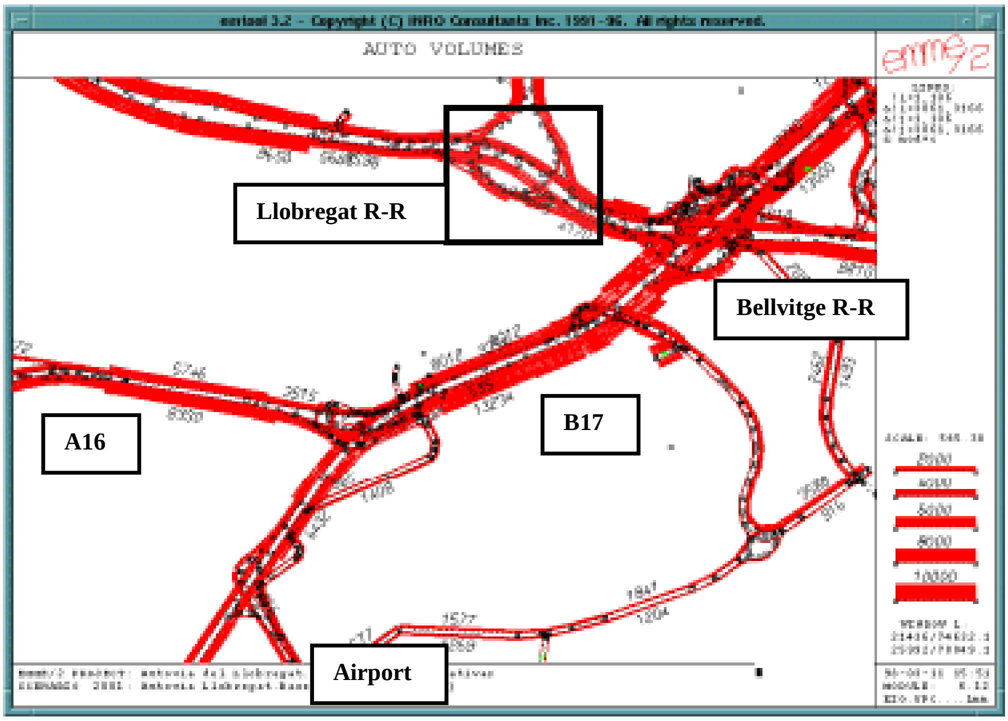
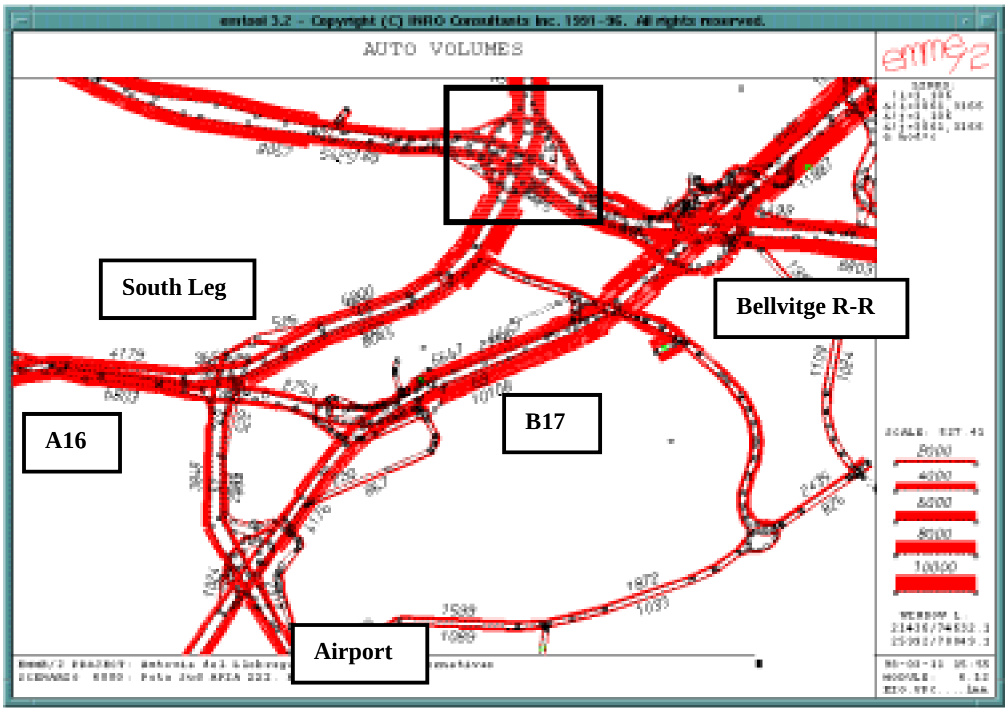


Figure 9. EMME/2: Base Scenario (up) and South Leg proposal 2 (down). Microsimulation area



The highlighted areas in **Figure 9** show the main differences in the proposed designs for one of the critical exchange nodes the so-called Llobregat Ring Road. The GETRAM to AIMSUN2 interface was used to build the microscopic models of the two alternative designs under study. The consistency between the network representations in AIMSUN2 and EMME/2 ensured by the interfaces, as described in Section 3, made then possible to use in the AIMSUN2 model the average pattern demands resulting from EMME/2 assignments in terms of turning percentages and volumes on input sections of the microscopic model.

The main differences between the two South Leg proposals depend on the design of the Llobregat ring-road complex and the connection between the A-16 motorway and the B-17 arterial for the South access to Barcelona. A detail of the ring-road represented by AIMSUN2 is shown in **Figure 10.**

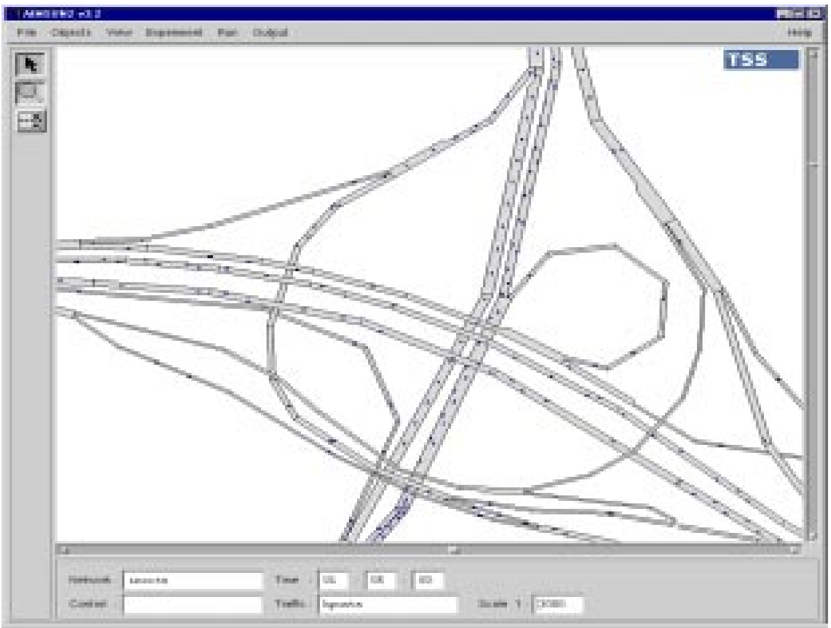


Figure 10. AIMSUN2 Llobregat ring-road. South Leg proposal 1 (above) and South Leg proposal 2 (below)

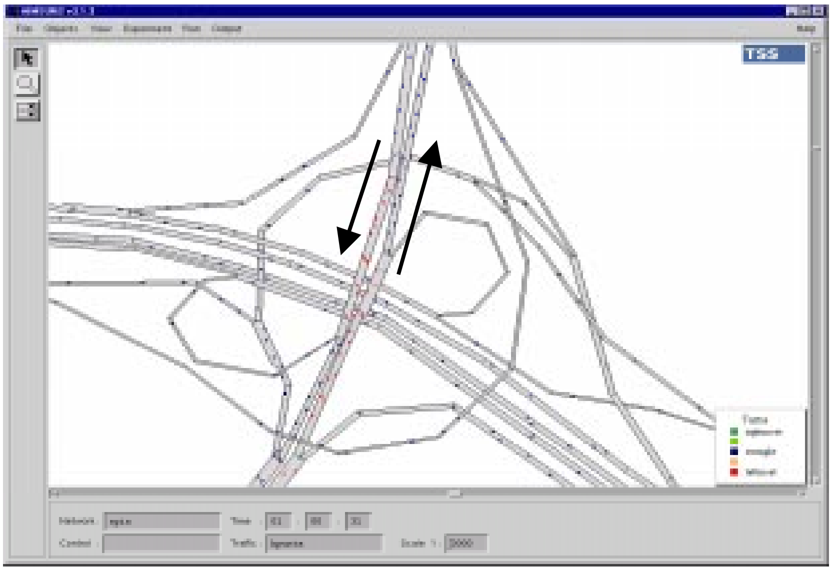
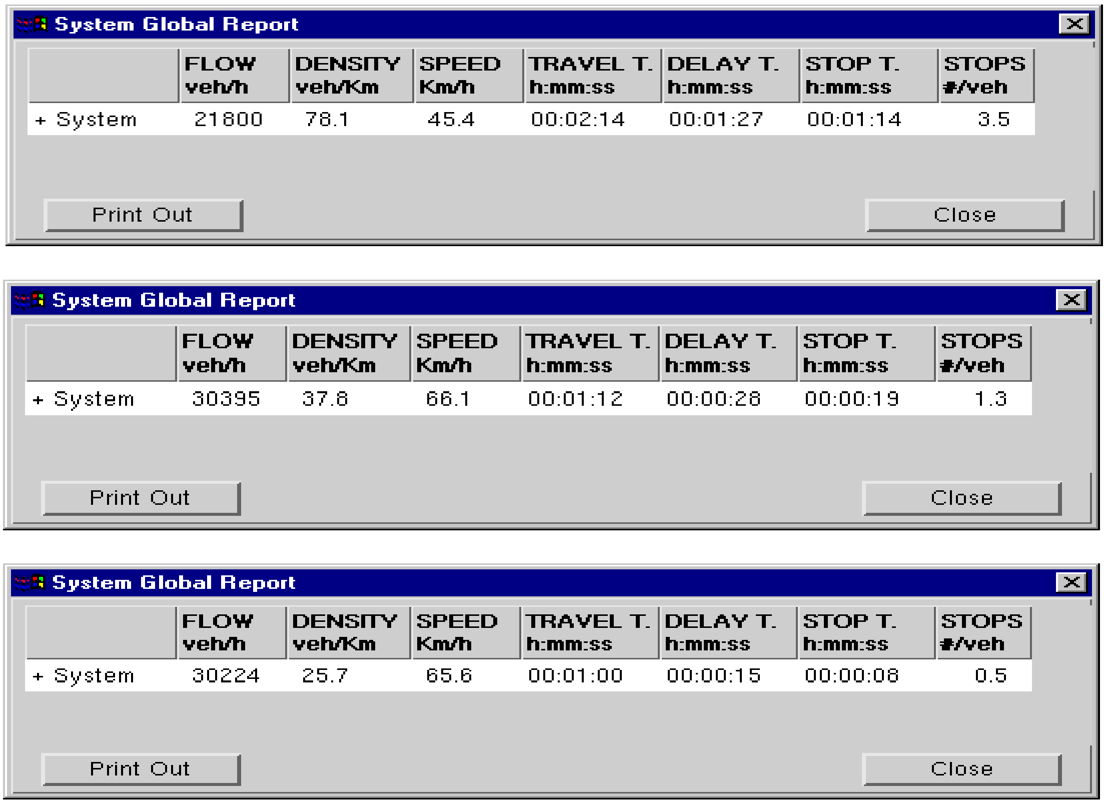


Figure 11 summarizes in terms of traffic indicators the output provided by AIMSUN2 for three hours of simulation time of the three alternative scenarios under study the Base scenario and the two proposals. Further than these overall results the microscopic simulation provides information on the dynamic evolution of traffic flows, queue lengths and other traffic variables over time, for specific road sections or selected sets of sections. This dynamic information is the basis of the decision making process and constitutes the way of differentiating the expected performance for the alternative designs.



System Global Report	FLOW veh/h	DENSITY veh/Km	SPEED Km/h	TRAVEL T. h:mm:ss	DELAY T. h:mm:ss	STOP T. h:mm:ss	STOPS #/veh
+ System	21800	78.1	45.4	00:02:14	00:01:27	00:01:14	3.5

Print Out Close

System Global Report	FLOW veh/h	DENSITY veh/Km	SPEED Km/h	TRAVEL T. h:mm:ss	DELAY T. h:mm:ss	STOP T. h:mm:ss	STOPS #/veh
+ System	30395	37.8	66.1	00:01:12	00:00:28	00:00:19	1.3

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System Global Report	FLOW veh/h	DENSITY veh/Km	SPEED Km/h	TRAVEL T. h:mm:ss	DELAY T. h:mm:ss	STOP T. h:mm:ss	STOPS #/veh
+ System	30224	25.7	65.6	00:01:00	00:00:15	00:00:08	0.5

Print Out Close

Figure 11. AIMSUN2 simulation results: general statistics for 3 hour peak period: Base, SL-Proposal 1 and SL-Proposal 2

The analysis of time varying traffic conditions is obviously a powerful assessment tool. The microscopic simulator collects statistical data for user defined time periods: every t seconds, minutes, etc. depending on the user's choice. To illustrate this aspect, for the two sections indicated with an arrow in figure 10, for the SL-Proposal 2, a graphical representation of the evolution of the traffic conditions every five minutes is shown in **Figure 12**.

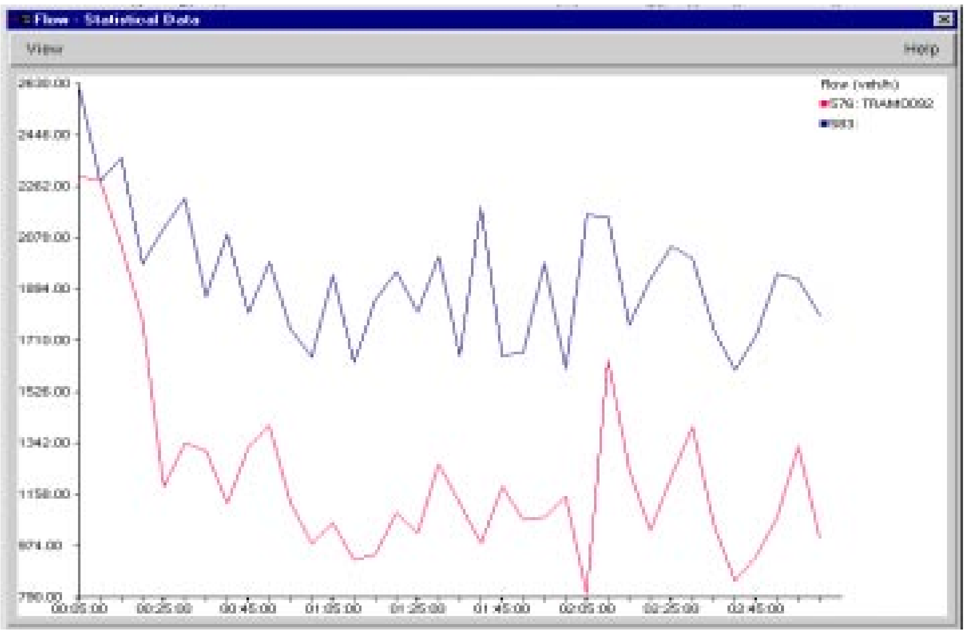

Figure 12. AIMSUN2 Simulation results: dynamic evolution of traffic conditions. South Leg-Proposal 2: sections marked with arrows

The global system dynamic evolution during the simulation horizon can also be summarized. Table 3 shows this information collected every 15 minutes during the three hours peak period of simulated time in the study for the South Leg Proposal 2.

Table 3. AIMSUN2 Simulation results: dynamic evolution of general traffic conditions. South Leg-Proposal 2

Global Periodical Statistics

	FLOW Veh/h	DENSTY veh/Km	SPEED Km/h	TRAVEL T. h:mm:ss	DELAY T. h:mm:ss	STOP T. h:mm:ss	STOPS #/Veh
Time : 00:15:00 + System	29212	17.1	69.6	0:00:54	0:00:12	0:00:03	0.3
Time : 00:30:00 + System	29311	24.7	68.0	0:00:56	0:00:10	0:00:05	0.4
Time : 00:45:00 + System	30384	26.4	66.2	0:00:59	0:00:13	0:00:07	0.5
Time : 01:00:00 + System	30135	26.0	66.8	0:00:59	0:00:14	0:00:08	0.4
Time : 01:15:00 + System	30451	26.7	65.2	0:01:00	0:00:15	0:00:08	0.5
Time : 01:30:00 + System	30511	27.4	65.1	0:01:01	0:00:15	0:00:08	0.5
Time : 01:45:00 + System	30563	27.2	65.1	0:01:02	0:00:16	0:00:10	0.5
Time : 02:00:00 + System	30627	27.5	65.1	0:01:01	0:00:16	0:00:09	0.5
Time : 02:15:00 + System	31087	26.8	65.2	0:01:01	0:00:15	0:00:09	0.5
Time : 02:30:00 + System	29773	27.4	64.2	0:01:03	0:00:17	0:00:10	0.6
Time : 02:45:00 + System	30349	27.9	63.2	0:01:06	0:00:20	0:00:13	0.7
Time : 03:00:00 + System	30287	26.8	63.6	0:01:03	0:00:17	0:00:10	0.7

To complete the simulation result analysis the concept of level of service has been applied. Six categories of level of service have been defined in terms of density intervals measured in vehicles per km, ranging from A (very good) to F (very poor), as shown in table 4.

Table 4. Definition of level of service according to density intervals (vehicles per km)

LEVEL OF SERVICE	*DENSITY FROM*	*DENSITY TO*
A	0	12
B	13	26
C	27	40
D	41	61
E	62	90
F	91	No limit

In the Base scenario and for the first hour of the peak period, the west access to the Llobregat ring-road has a level of service C, and the A-16 motorway and the B-17 road (south access to Barcelona) both have a level of service B. There are some service lanes with long queues from the Llobregat ring-road (Barcelona-bound) and level of service D. The connection to the airport shows a level of service B-C. During the second hour of the peak period, we find a level of service D-E in the southern area (B17 south access) and a worsening of the situation in the service lanes around the Llobregat ring-road, with a level of service C-D. The connection to the airport is C-D. In the third hour, the Llobregat ring-road area presents long queues and level of service D, and the B17 access maintains a level of service D; however, on average, traffic conditions tend to improve. The critical points in the network are: the connection between the A-16 motorway and the B-17 south access to Barcelona, the connection from the B-17 to the airport, and the service lanes close to the Llobregat ring-road.

In the South Leg Proposal 1, during the first hour of the peak period there are no problems either in the access to the airport or in the B-17, due to the South Leg's additional infrastructure. In the second hour, the level of service at the black spots remains at level B. A level of service C appears in the Bellvitge ring-road, and the level of service of the B-17 is B-C. During the third hour the level of service of the B-17 reaches C and the problem on the Bellvitge ring-road remains.

In the South Leg-Proposal 2, during the first peak hour there are no problems. In the second hour, the level of service at the black spots remains at level B. The level of service of the B-17 is B. During the third hour the level of service of the B-17 is B-C. No problems are detected in the service lanes.

The Base scenario presents serious problems that are solved by both of the SL proposals. The main difference between the proposals lies in the volumes in the South Leg and B-17 accesses: SL-Proposal 1 benefits the load on the B-17 access, but SL Proposal 2 benefits the load on the South Leg access. Local problems in service lanes appear more frequently in SL-Proposal 1, and could constitute a source of future congested points.

CONCLUSIONS

The paper describes a procedure for evaluating private transportation planning alternatives, which depends on how well macroscopic and microscopic traffic models can be integrated through a common user-friendly environment (GETRAM). The GETRAM editor reduces drastically one of the most time-consuming aspects in transportation modeling: the network building stage. The proposed methodology has been successfully used in several traffic studies: a Zone Control Access project in Barcelona for the Demand Management European Project Gaudi, a urban transportation study for the city of Vigo, a medium sized city in the Northwest coast of Spain, and the transportation planning and design study for the South Leg of Barcelona's Ring Roads that illustrates in this paper the use of the methodology.

GETRAM3.2 and AIMSUN2 have been developed by the Department of Statistics and Operational Research of the Technical University of Catalonia and are currently distributed by TSS (Transport Simulation Systems).

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