A METHODOLOGY FOR PRIVATE TRANSPORTATION PLANNING ASSESSMENT: GETRAM ENVIRONMENT. AN APPLICATION TO BARCELONA'S METROPOLITAN AREA

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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.

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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 models 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 (see Figure 2). 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.
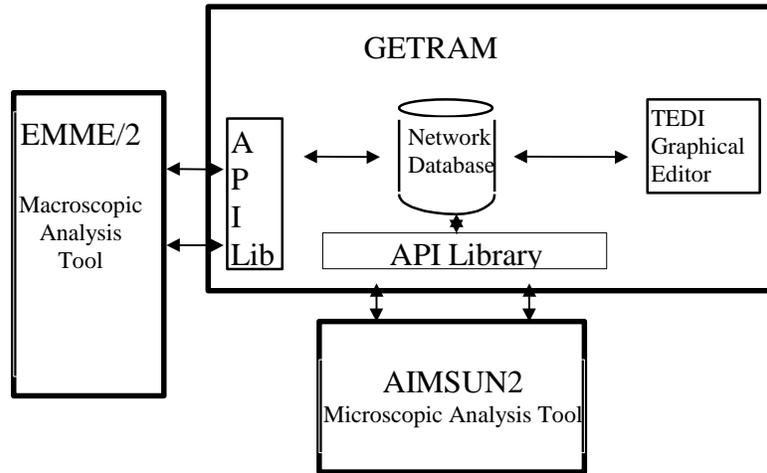
Figure 2. GETRAM Conceptual Diagram: Integration of Macroscopic and Microscopic Analysis Tools

AIMSUN2 (Ferrer & Barceló, 1994) is a microscopic simulator integrated into GETRAM and capable of reproducing the real traffic conditions on an urban network which 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 a 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.
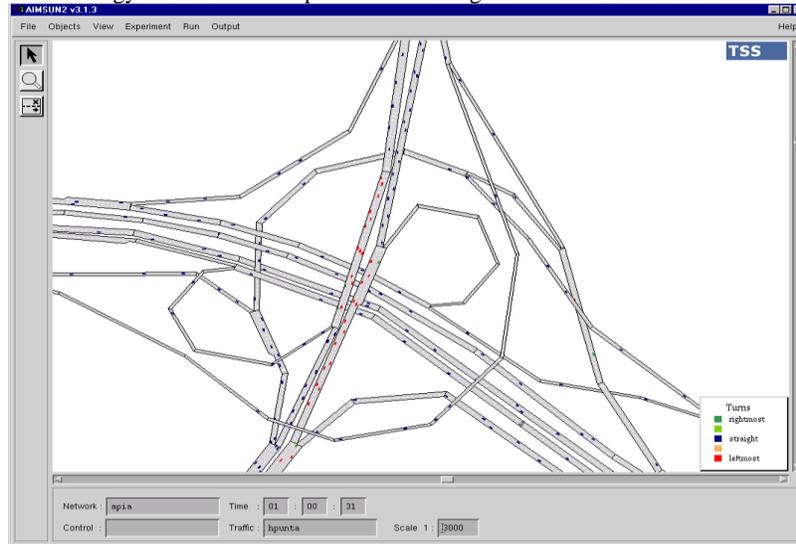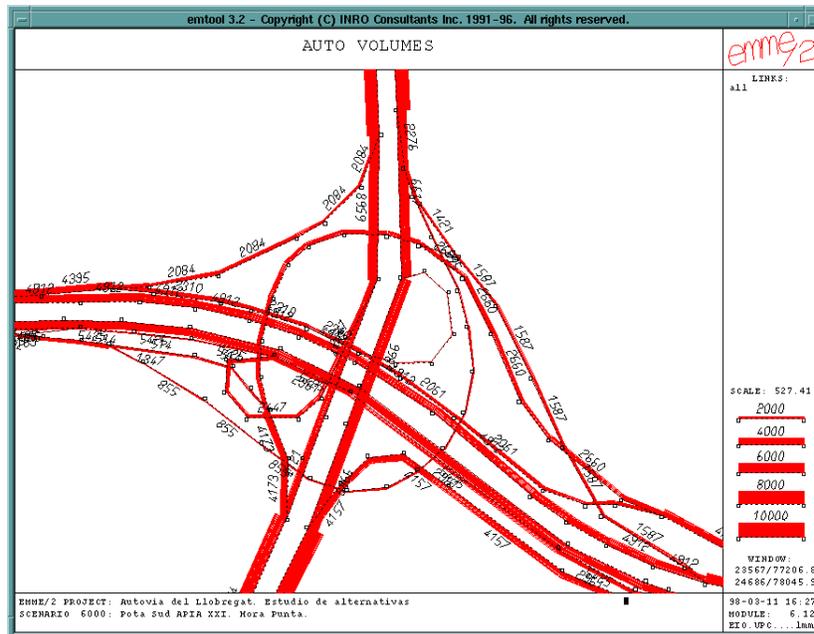
Figure 3. AIMSUN2 simulation vs EMME/2 Assignment: Llobregat Ring-road in one of the scenarios.

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 3.11 Module Input 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.).
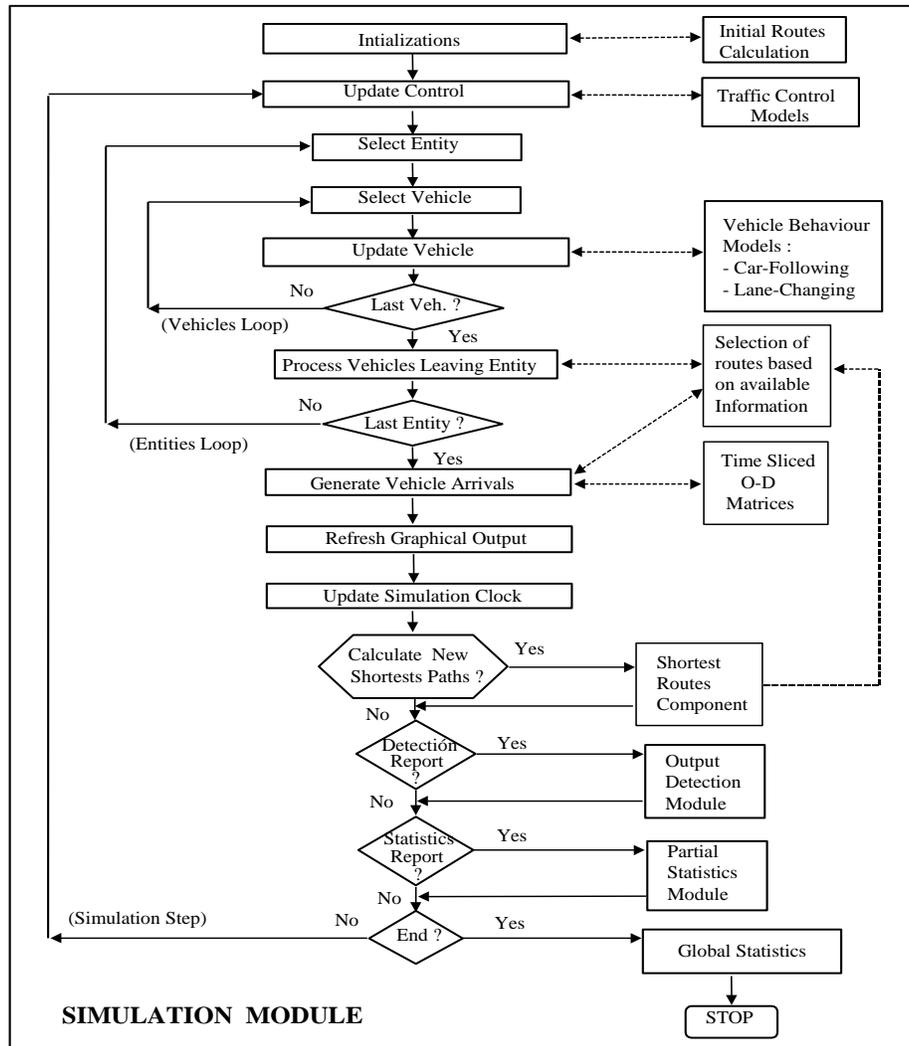
Figure 4. AIMSUN2 Simulation Process

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 fullfil 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, by clicking on the screen, 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 generates a compatible EMME/2 network and turning movement description, in Batch Entry formats for 2.11 and 2.31 Modules. Once in GETRAM, select the File menu and the Export option.
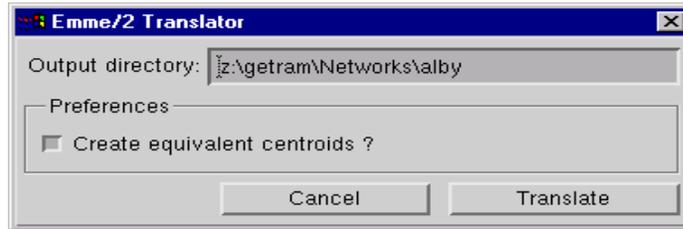
   An EMME/2 network consists of modes, nodes and links (which constitute the base network), turns, transit vehicles, transit lines and transit segments. These components of the network have three types of attributes: standard attributes, extra attributes (user-defined and not considered in the current 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:

- To avoid further problems when analyzing equilibrium assignment results, the unit of length and the length of units of coordinates units have to be defined in the EMME/2 environment (module 1.23). GETRAM usually in UTM coordinates and by default the EMME/2 Databank is set to be compatible. The default unit of length in EMME/2 is *km* and by default the user coordinate unit is taken to be the same as the unit of length.
- Modes must be loaded (Module 2.01). The mode table compatible with the GETRAM interface is shown in `Table 1`.
- Transit vehicles must be loaded (Module 2.02). 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 (see `Table 2`).
- Volume delay and penalty functions must be loaded (Module 4.11). EMME/2 allows six classes of functions: auto volume-delay (fd$n$), turn penalty (fp$n$), transit time (ft$n$), auto demand (fa$n$), transit demand (fb$n$) and user function (fu$n$). 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 default set of functions is shown in `Table 3`.
- The destination `scenario` must be created unprotected against modifications (otherwise, change protection flags properly in Module 1.22). Node, link and turning movement tables have to be initialized (Module 2.12 options 2 & 1 and Module 2.31 option 1).

```
t modes init
a c car        1   1   0.00    0.00    0.00    0.00
a b bus        2   25
a r renfe      2   25
a g fgc        2   25
a m metro      2   25
a n tram       2   26
a p pedestrian 3   54   0.00    0.00    0.00    0.00    4.00
a t transfer   3   33   0.00    0.00    0.00    0.00    4.00
a h HOV        4   33   0.00    0.00    0.00    0.00
```

Table 1. GETRAM to EMME/2 interface: table of compatible modes

```
t vehicles init
a  1 renshor   r   999   300   500  0.00   0.00   0.00   0.00 999.00
a  2 renlong   r   999   600   900  0.00   0.00   0.00   0.00 999.00
a  3 bushort   b   999    51   100  0.00   0.00   0.00   0.00   2.50
a  4 buslong   b   999    71   200  0.00   0.00   0.00   0.00   4.50
a  5 fgcshor   g   999   300   300  0.00   0.00   0.00   0.00 999.00
a  6 fgclong   g   999   400   400  0.00   0.00   0.00   0.00 999.00
a  7 metro     m   999   120   500  0.00   0.00   0.00   0.00 999.00
a  8 tram      n   999   120   300  0.00   0.00   0.00   0.00   4.50
```

Table 2. GETRAM to EMME/2 interface: table of compatible transit vehicles

```
t  functions
a fd1  =0
a fd2  =length
a fd5  =length*( (ms(2) * 31.35 * ms(1) ^ 4.7 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1+ 5.5* ms(1) ^ 5.7)
          .max. (1 + 5.5 * (get(1)) ^ 5.7))
a fd17 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 4.5 ).max.(1+2.5*get(1)-8*get(1)^2+12*get(1)^3 ) )
a fd18 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 4.5 ).max.(1+2.5*get(1)-8*get(1)^2+12*get(1)^3 ) )
a fd21 =length*( (ms(2) * 22 * ms(1) ^ 3.6 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1 +4.8* ms(1) ^ 4.6)
          .max. (1 +4.8 * (get(1)) ^ 4.6))
a fd22 =length*( (ms(2) * 25.6 * ms(1) ^ 2.2 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1 + 8 * ms(1) ^ 3.2)
          .max. (1 + 8 * (get(1)) ^ 3.2))
a fd23 =length*( (ms(2) * 25.6 * ms(1) ^ 2.2 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1 + 8 * ms(1) ^ 3.2)
          .max. (1 + 8 * (get(1)) ^ 3.2))
a fd24 =length*( (ms(2) * 22 * ms(1) ^ 3.6 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1 +4.8* ms(1) ^ 4.6)
          .max. (1 +4.8 * (get(1)) ^ 4.6)) + ms(5)*
          (1 + 10*get(1) - 40.5*get(1)^2 + 45*get(1)^3)
a fd25 =length*( (ms(2) * 24.3 * ms(1) ^ 4.5 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1+4.45* ms(1) ^5.5)
          .max. (1 + 4.45* (get(1)) ^ 5.5)) + ms(5)*
          (1 + 10*get(1) - 40.5*get(1)^2 + 45*get(1)^3)
a fd26 =length*( (ms(2) * 24.3 * ms(1) ^ 4.5 *
          (put(volau/(lanes*ul2)) - ms(1)) + 1+4.45* ms(1) ^5.5)
          .max. (1 + 4.45* (get(1)) ^ 5.5)) + ms(4)*
          (1 + 10*get(1) - 40.5*get(1)^2 + 45*get(1)^3)
a fd28 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 3 ).max.(1+2.5*get(1)-8*get(1)^2+10*get(1)^3 ) )
a fd29 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 3 ).max.(1+2.5*get(1)-8*get(1)^2+10*get(1)^3 ) )
a fd30 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 3 ).max.(1+2.5*get(1)-8*get(1)^2+10*get(1)^3 ) )
a fd31 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 4.5 ).max.(1+2.5*get(1)-8*get(1)^2+12*get(1)^3 ) )
a fd33 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 3 ).max.(1+2.5*get(1)-8*get(1)^2+10*get(1)^3 ) )
          + ms(5)*(1 + 10*get(1) - 40.5*get(1)^2 + 45*get(1)^3)
a fd35 =length*( (ms(2) *17.2*(put(volau/(lanes*ul2))-ms(1))
          + 3 ).max.(1+2.5*get(1)-8*get(1)^2+10*get(1)^3 ) )
          + ms(4)*(1 + 10*get(1) - 40.5*get(1)^2 + 45*get(1)^3)
```

Table 3. GETRAM to EMME/2 interface: table of compatible functions. Bold letters indicate the expression in Figure 5

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: otherwise, an error will arise when trying to load the Batch Entry file with Module 2.11.

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`) are shown in Table 4. 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 (see Table 5). 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.

TYPE	MAX. SPEED	LANE CAPACITY	VDF	LINK TYPE DESCRIPTION
1	0	9999	1	**Connector**
2	10	9999	2	Connector
3	15	9999	2	Connector
4	30	9999	2	Connector
5	60	9999	2	Connector
10	120	2100	5	**Motorway**
31	80	1000	17	Motorway Exit
32	60	900	18	Motorway Exit
33	50	600	18	Motorway Exit
40	90	1200	21	**Interurban Road**
41	100	1200	21	Interurban Road
42	80	1100	21	Interurban Road
43	60	950	21	Interurban Road
44	50	800	22	**Mountain Road**
45	40	600	22	Mountain Road
46	40	300	22	Mountain Road
47	30	250	22	Mountain Road
50	50	800	23	**Urban Road without Lights**
51	50	700	24	Urban Road with Lights
52	60	900	23	Urban Road without Lights
60	50	900	25	**Arterial**
61	50	650	26	Arterial (not coordinated)
70	50	800	28	**Street without Lights** (>=2 lanes)
74	50	700	28	Street without lights
71	50	500	29	Street without lights
72	40	350	30	Street without lights
73	30	300	31	Street without lights (=1 lane)
80	50	700	33	Street with lights (>=2 lanes)
81	40	500	35	Street with lights (1 lane)

Table 5. GETRAM to EMME/2 interface: table of compatible link types and functions

FP function	Greather than		Less equal than
1		Max_speed	10

2	10	*Max_speed*	20
3	20	*Max_speed*	30
4	30	*Max_speed*	40
5	40	*Max_speed*	*No limit*

Table 6. GETRAM to EMME/2 interface: Turn Penalty functions according to maximum turning speed

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*.
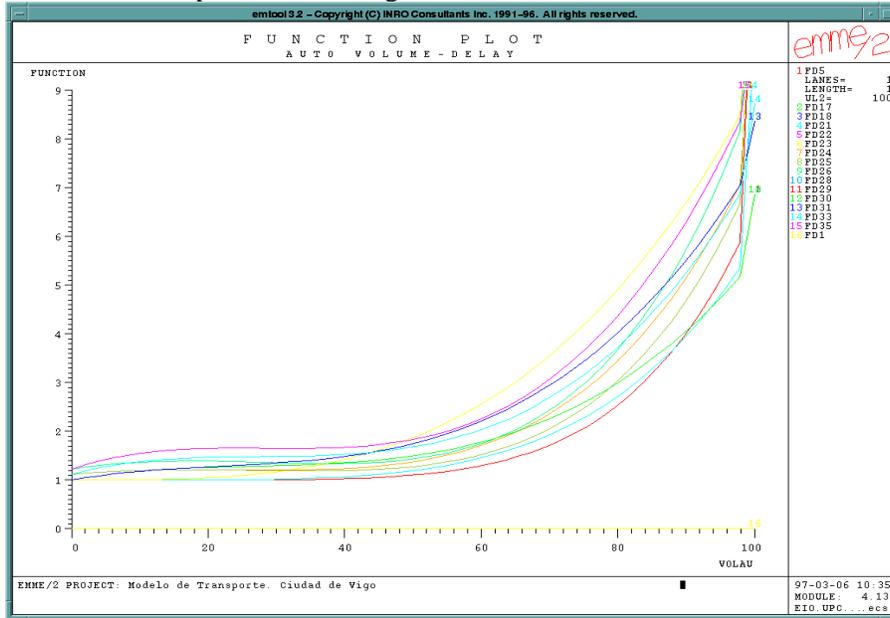

Figure 5. GETRAM to EMME/2 interface: Partial representation of volume delay functions.

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 6 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* $i \rightarrow m \rightarrow j, \quad i \rightarrow m \rightarrow k,$ ... and so on and only movements $i \rightarrow m \rightarrow n, \quad n \rightarrow m \rightarrow j, \quad n \rightarrow m \rightarrow k \quad and \quad n \rightarrow m \rightarrow l$ are allowed.
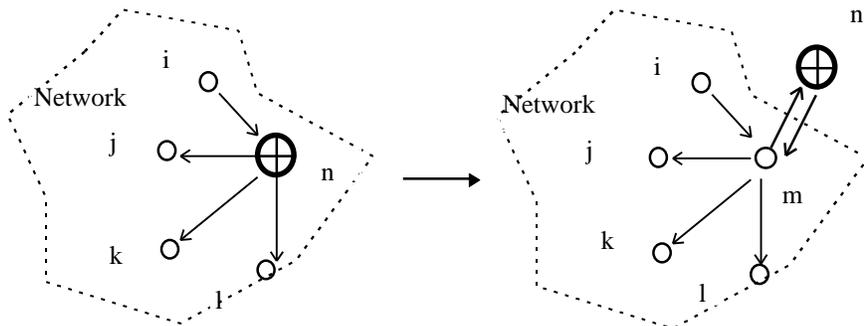

Figure 6. GETRAM to EMME/2 interface: total equivalent centroid-connectors transfer

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 7.
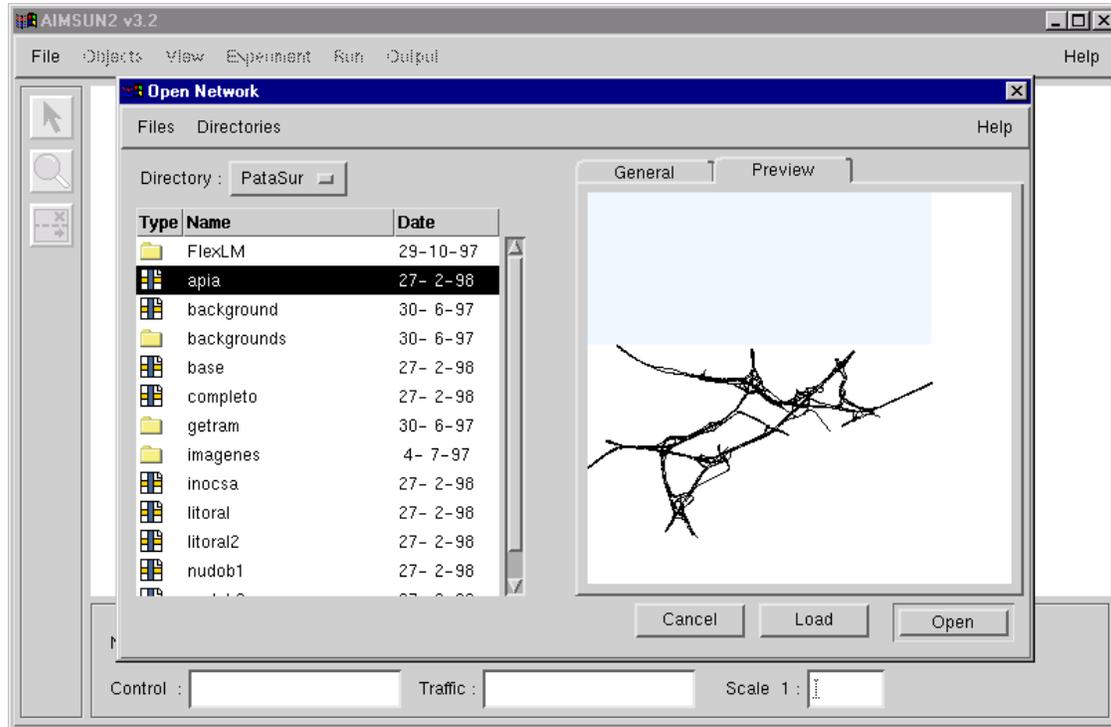

Figure 7. GETRAM: Starting an AIMSUN2 simulation

EMME/2 TO AIMSUN2 VIA GETRAM

It offers several possibilities that will be 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 (`.stt  file`). The structure of an `.stt` file is shown Figure 8.

- 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 dialogue which is partially shown in Figure 9.

- 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.

```
 * Network state specification, file name 'F:\nets\apia5r\hpunta\hpunta.stt'
 * Time offset, nbsections, nbvehmods
   0   793  1
* Section --------------------------------
* idsection, nbentrance_points, nbturnings
 75  2  0
 * Entrance point --------------
 * VehMod: entrance flow ---
 2000.000000
 * Entrance point --------------
 * VehMod: entrance flow ---
 2000.000000
 * Section -------------------------------
 * idsection, nbentrance_points, nbturnings
 102  1  2
 * Entrance point --------------
 * VehMod: entrance flow ---
 4312.000000
 * Turning: speed, nbveh, nbveh_stopped, percentage
 50.000000  27.500000  0.000000  0.420000
 * Turning: speed, nbveh, nbveh_stopped, percentage
 50.000000  27.500000  0.000000  0.580000
 * Section -------------------------------
 * idsection, nbentrance_points, nbturnings
  476  1  0
```

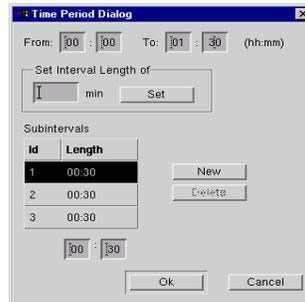Figure 8. AIMSUN2: An example of traffic conditions file
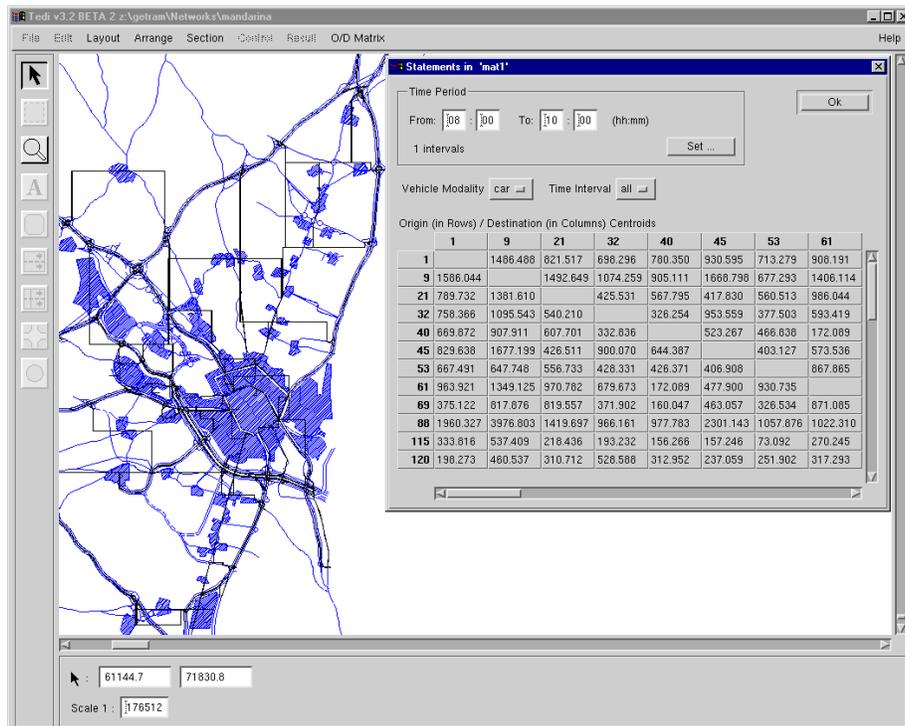
Figure 9. GETRAM interface from EMME/2 to AIMSUN2: A time-sliced OD matrix definition

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 infrastructural 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 authors are responsible for assessing several 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.

The semi-authomatic building of the required transportation graphs by the macroscopic tool EMME/2 and the microscopic tool AIMSUN2 was performed with the graphical editor of GETRAM (called TEDI), which enables the attributes of network sections involved, i.e. number of lanes, width, speed, length, capacity, to be defined by using a digitalized map of the study area. From GETRAM internal binary format, an automatic process generates either the macroscopic network and turning movements description in EMME/2 batch entry format or the microscopic network description in AIMSUN2 entry format, for the whole area or a part of the area requiring detailed analysis by microscopic simulation. 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 10.

```
----------------------------- 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 10. 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. This information came from the 1991 Census. During the present study (1997), a large

scale mobility survey was conducted in the area, but results did not become available soon enough for inclusion. 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 7 shows the total number of trips, after adjustment because of 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 11.

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

Table 7. EMME/2: O/D totals after adjustment because of traffic counts

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.
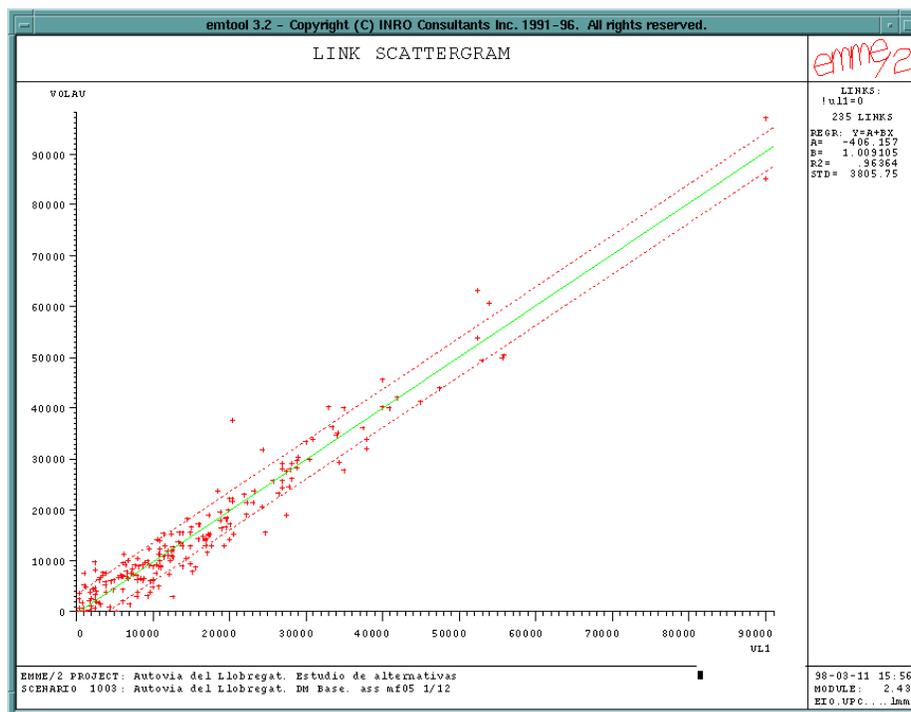

Figure 11. EMME/2: Observed versus predicted volumes after adjustment. Daily period

Macroscopic assignment results provided by EMME/2 on the Base and South Leg proposal scenarios in the microscopic simulation sub-area are shown in Table 8.

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*

Table 8. EMME/2 results. Base and South Leg proposal scenarios: microscopic simulation area
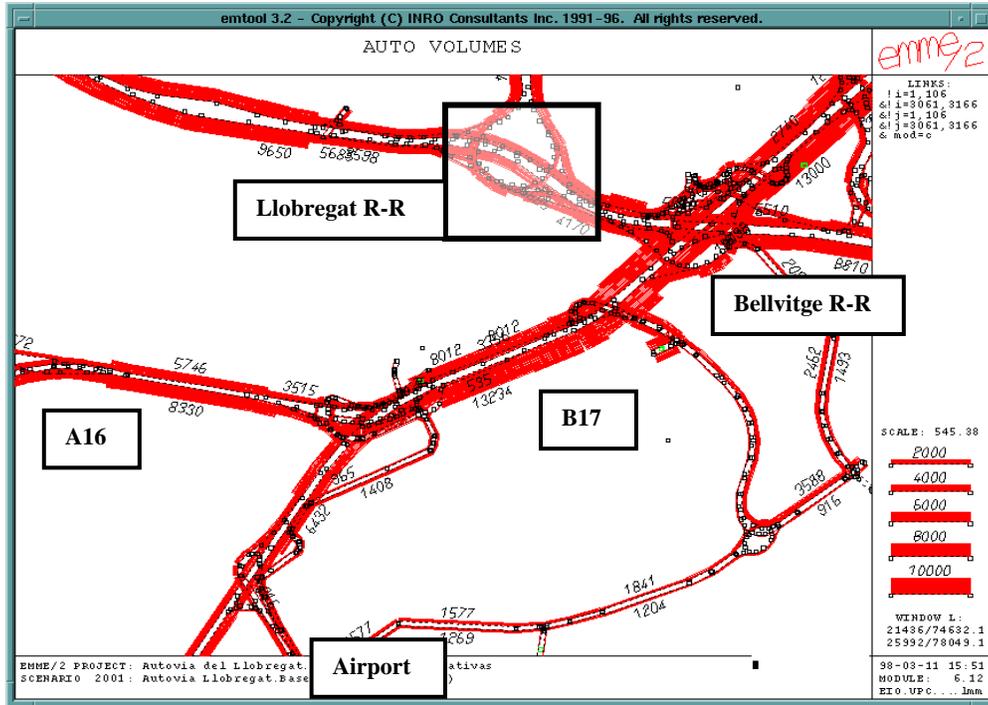
Figure 12. EMME/2: Base Scenario (up) and South Leg proposal 2 (down). Microsimulation area
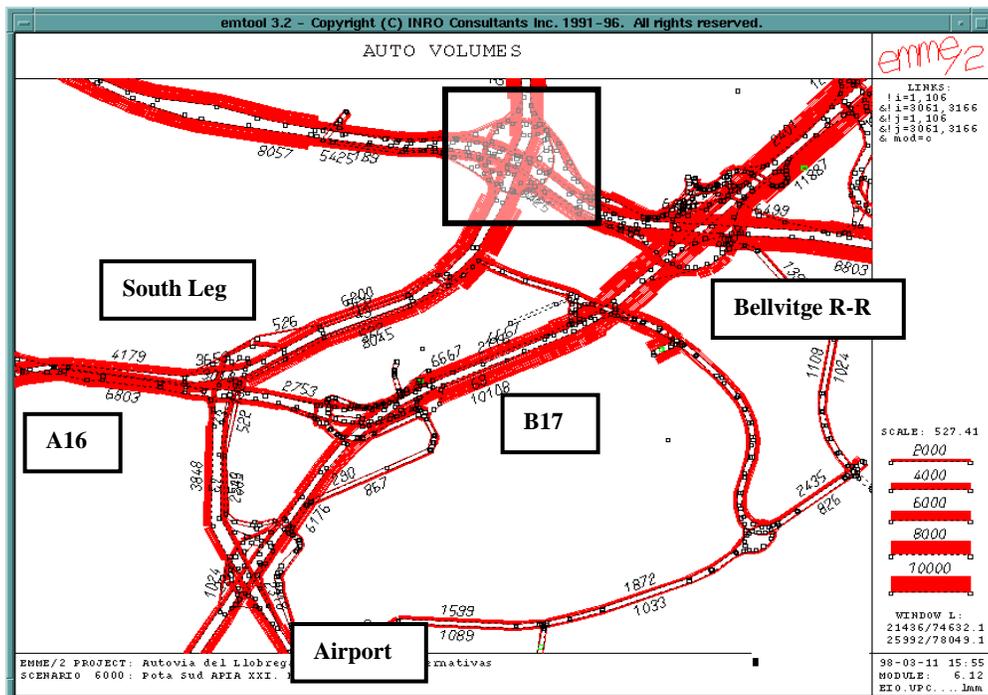
Some proposals for improving the designs were formulated at the conclusion of the study. For microscopic simulation, the detailed network description was submitted by GETRAM to the AIMSUN2 simulator, the pattern of demand was provided by the results of EMME/2 assignment to the selected scenarios, in terms of turning probabilities and volumes to input sections of the microscopic simulation sub-area. The microscopic simulation areas, for the Base and South Leg proposal 2 scenarios are shown in Figure 12. The Llobregat ring-road is highlighted.

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 Figure 13.
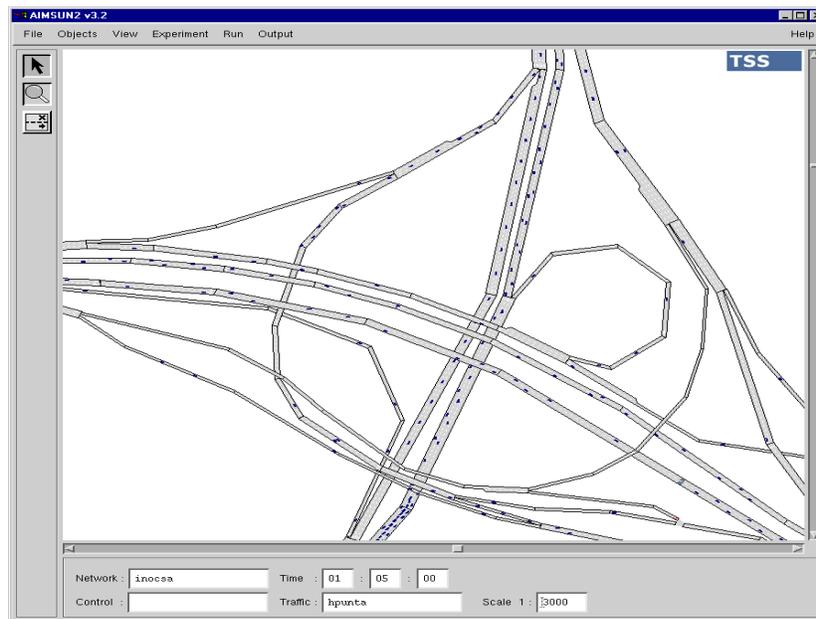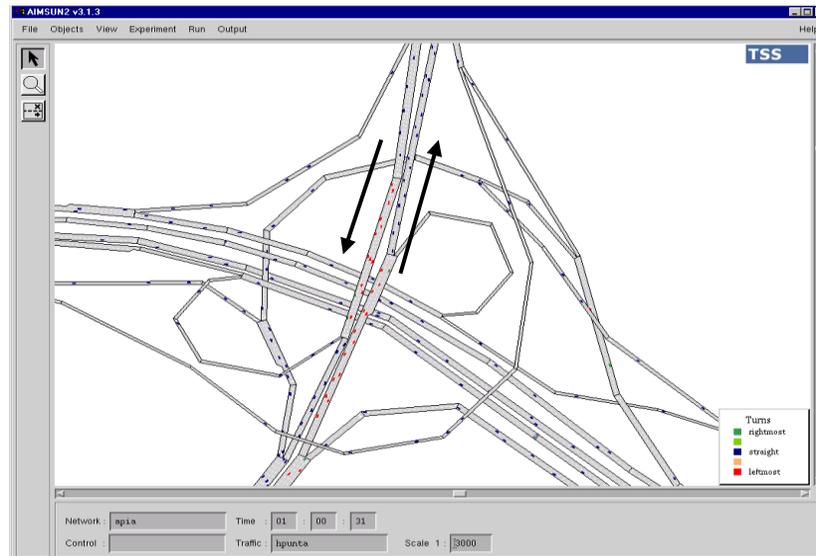

Figure 13. AIMSUN2 Llobregat ring-road. South Leg proposal 1 (above) and South Leg proposal 2 (below)

The AIMSUN2 simulation of conditions in the 3 hour peak period provides the traffic indicators shown in Figure 14 for the Base scenario and the two proposals studied. At any moment in the simulation time, the traffic state and the movement of the vehicles can be visualized (see Figure 13).
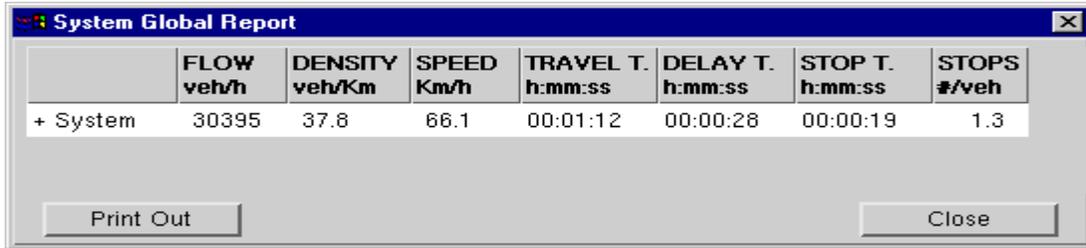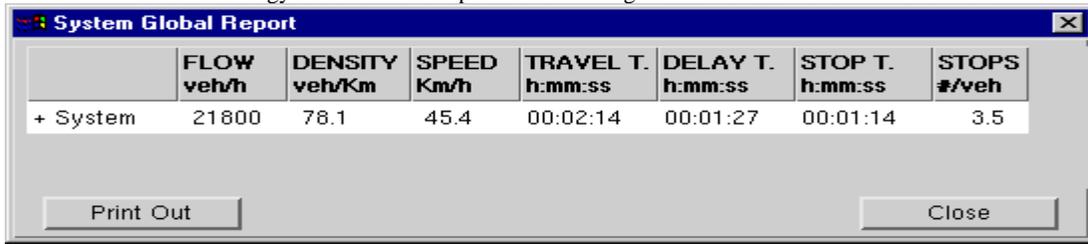
Figure 14. AIMSUN2 simulation results: general statistics for 3 hour peak period: Base, SL-Proposal 1 and SL-Proposal 2

The dynamic evolution of the traffic conditions in selected sections can easily be visualized by using the *Statistics Menu*. Every five minutes (or less, according to user definition), traffic conditions are computed at section and general levels. For the two sections indicated with an arrow in Figure 13 for the SL-Proposal 2, a graphical representation of the evolution of the traffic conditions every five minutes is shown (Figure 15).
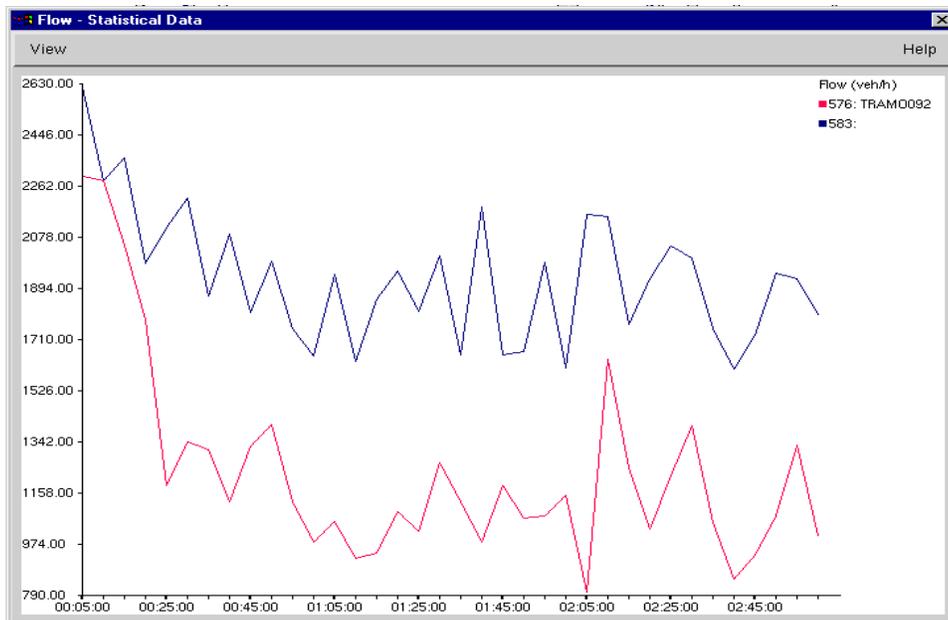

Figure 15. AIMSUN2 Simulation results: dynamic evolution of traffic conditions. South Leg-Proposal 2: sections marked with arrows

The evolution of the traffic conditions at fix time intervals and at a general level, i.e., the average of the conditions in each section, can also be computed and employed as an assessment tool. A time interval of 15 minutes is taken for the results shown in Table 9 for South Leg-Proposal 2 in peak period simulation.

```
 Global Periodical Statistics

                 FLOW    DENSTY   SPEED   TRAVEL T.   DELAY T.   STOP T.   STOPS
                 Veh/h   veh/Km   Km/h    h:mm:ss     h:mm:ss    h:mm:ss   #/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
```

Table 9. AIMSUN2 Simulation results: dynamic evolution of general traffic conditions. South Leg-Proposal 2

In the analysis of the results, the concept of level of service has been employed, ranging from A (very good) to F (very poor). Categories A to F are defined according to density intervals expressed in vehicles per km (see Table 10).

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

Table 10. Definition of level of service according to density intervals (vehicles per km)

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

This article 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 authors applied the procedure described in several local studies, such as traffic studies in Barcelona's Historical District (La Ribera), in Castellón (a small city 200 km south of Barcelona) and Vigo (a medium-sized city on the Northwest coast of Spain). In the Vigo study, the bus network was also modeled. This feature is not yet incorporated into the GETRAM network editor. However, the base private network was built with the GETRAM editor and the transit lines over the GETRAM nodes were defined through an external procedure based on Microsoft Access DB.

GETRAM3.1 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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