SAS (Scenario Analysis System): a software platform combining micro and macro approaches for transportation analysis.

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Abstract

The interest in interfacing Macroscopic models for transportation analysis with Microscopic models raised time ago as a consequence of the requirement for a deeper analysis in transport planning where the long term views proper of planning applications had to be combined with short term views on the potential impacts of the alternative designs when subject to the time dependent variability of the demand. Interfacing a macroscopic model of a road network , as for instance one built with EMME/2, with a microscopic model as for example one built with AIMSUN requires a very specific methodology to ensure the consistency of the network representations at both levels, the correspondence of the demand structure (i.e. centroids and connectors), and a coherent exchange of information between the two levels. This problem was addressed in a paper presented at the 9th European EMME/2 User's Group Conference held in Barcelona in 2000 (1).

There has also been another reason to improve the exchange of information between the two approaches at the level of Origin-Destination matrices. The current trend in microscopic traffic simulation is based on a new paradigm in which individual vehicles travel from origins to destinations along the available paths according to route choice models, paths are timely updated according to changes in traffic conditions on the road network (2, 3). Strictly speaking this means that time-depend origin-destination matrices have to be supplied as input to the microscopic simulator. The theoretical approaches developed so far to estimate dynamically origin-destination matrices are suitable only for very specific types of road networks, i.e. linear structures as in the case of freeways and motorways, in which the only origins and destinations are the on and off-ramps. Unfortunately these approaches do not work in the case of true network structures and even less when networks are of a sensible size as it is the case with the real life applications. A quick and dirty solution to this problem could be based in manipulating the Origin-Destination matrices using information from OD surveys, if available, to time-slice the global OD matrices, extract the local OD matrices (traversals) for the smaller areas to be analysed microscopically, and adjust these matrices on basis to the link flow counts of the subnetwork spanning the area of interest. The methodology proposed in this paper is based on the features and functions supported both by EMME/2 and AIMSUN to assist the analyst in automatically generate the EMME/2 model from an AIMSUN model, graphically select the subnetwork of interest, generate the traversal, adjust the traversal and import the adjusted traversal matrix into the AIMSUN model of the subnetwork to perform the simulation experiments of interest.

SAS (Scenario Analysis System) is a graphic software platform that embeds the microscopic traffic simulator AIMSUN, and interfaces EMME/2, providing the analyst with a friendly user interface to perform the above described operations. SAS can be used for detailed planning analysis as well as for strategic analysis to support traffic management policies in specific scenarios (4). This paper describes the methodology, the structure of the system and a demonstration of how it works. The demonstration is based on the models built to support traffic management on the road network consisting of the motorways and main highways of the Land of Hessen in Germany.

1. INTRODUCTION

The **Scenarios Analysis System** (SAS) is based on a combination of an AIMSUN microscopic traffic simulation model and an EMME/2 transport planning model of the road network, or in specific scenarios for sub-networks of the road network under study, to define, verify and optimise traffic management strategies, evaluate the expected impacts of the strategies and determine the triggers to activate strategies according to prevailing traffic conditions. SAS operation is assisted by three auxiliary tools:

- GETRAM/TEDI: The Generic Environment for Traffic Analysis and Modelling and its associate graphic editors TEDI, that support the network edition.
- AIMSUN, the microscopic traffic simulator providing the dynamic traffic models for the evaluation of the traffic management strategies, interactively activated from SAS.
- EMME/2 a transport planning software providing the macroscopic traffic models for traffic assignment and OD matrix adjustment to deal with the analysis of the demand patterns for the selected scenarios.

The main objective of SAS is to allow the fast and convenient manipulation of input data to create simulation scenarios and to present result data in a compressible way. It has two main components:

- The simulation experiment specification and
- The result analysis.

The simulation experiment specification includes:

- The set-up of a Problem Network (either the network of the whole area or a sub-network),
- The creation, modification and adjustment of O/D matrices (global for the whole area as well as local or traversal for the sub-networks),
- The addition of traffic management policies and their triggers and
- The simulator tuning.

The result analysis includes:

- The output data presentation and
- The comparative study of the performance of a solution, either with previous solutions or with real data.

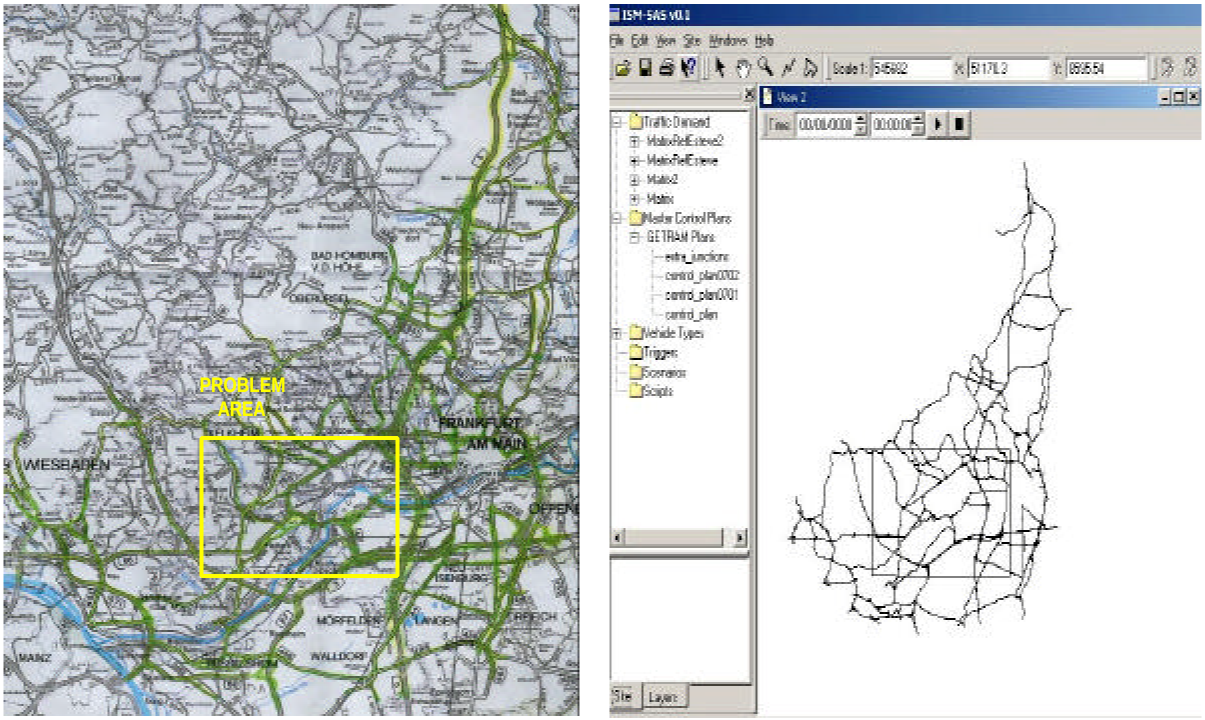
Since a problem can have different solutions and since these solutions cannot be obvious the user can define several experiments combining different policies until he/she finds the best option. During this experimentation the user can reuse previous solutions and add new ones. Then the user can compare the performance of the new solution with either real data or other solutions. These two components can be used iteratively until a satisfactory solution is found. These components provide the support for the generation, evaluation and optimisation of traffic management strategies.

The SAS operation is illustrated in Figure 1. In this figure a potential Problem Network is shown. A Problem Network corresponds to a sub-network of the road network on which specific traffic problem may arise or is identified by the user.

The Problem Network is defined graphically by the user opening a window on the screen on which the WAYFLOW network is displayed. The yellow rectangle in Figure 1a corresponds to the selected Problem Network. A Problem Network is characterized by:

- The Road Network within the defining window

- An OD Database linked to the Problem Network with the various demand patterns for the Problem Network under various circumstances (season, day of the week, time of the day, special event, etc.)
- A Strategy Database containing the specifications of the potential traffic management strategies to operate on the Problem Network depending on the identified or potential traffic problem and the demand pattern.



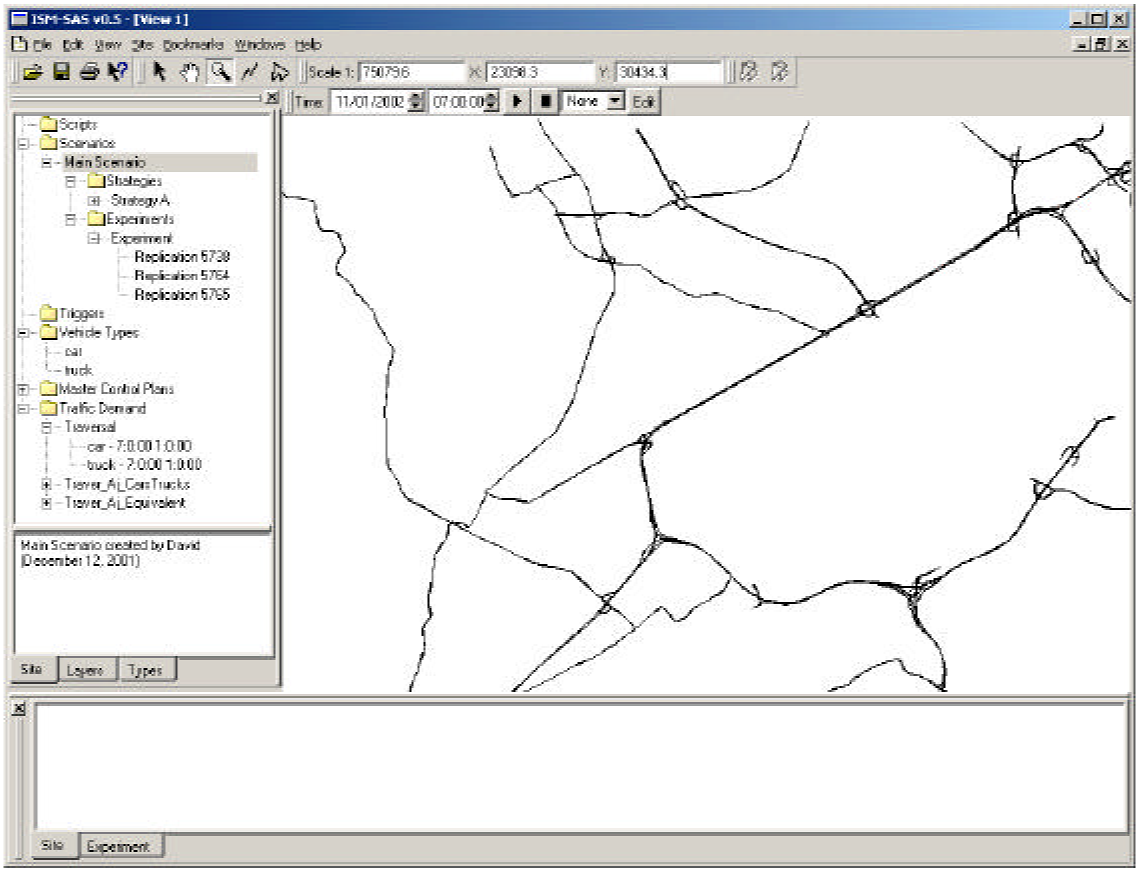
(1a) (1b)

Figure 1

The operation of the Site Creation and Problem Network definition in SAS is illustrated in Figure 1b, where the SAS working area displays the previously created model of the road network of the site (The WAYFLOW network of Hessen shown in Figure 1a). The rectangle drawn by the operator on the network model corresponds to the Problem Network highlighted in yellow in Figure 1a. Once the Problem Network has been defined the operator activates the extraction of the sub-network model for the Problem Network, this is the first step in the process of generating the scenario to be analysed and the automatic production of the AIMSUN microscopic simulation model to analyse the scenario and assess the potential impact of the proposed traffic management strategies to alleviate the identified traffic problem. The figure 2 depicts the automatically generated GETRAM model for the Problem Network.

2. O/D CALCULATION (OD TOOL)

SAS assumes explicitly that the traffic analysis tools that it contains, and namely the microscopic simulation with AIMSUN provide the support for a dynamic analysis of traffic scenarios taking into account the time variability of traffic phenomena. That means that the analysis tools require inputs describing the traffic mobility patterns and, if possible, their time dependencies. For example, the proper assessment of the impacts of management strategies implying rerouting and diversion needs such type of input. A way of providing this input is through the appropriated OD matrices. The objective of the OD Tool is to provide a module supporting the functions that can generate the requested input. Examples of such functions are: Matrix Edition, Generation of the local traversal OD matrix for the selected Problem Network and time period, Adjustment of the local traversal from the available traffic counts for that time period to account for the explicit time dependencies, Modification of the adjusted traversal to account for increases or decreases in the traffic demand at given zones to deal with special events, Modification of the adjusted demand to account for addition or deletion of traffic zones (deletion and insertion of centroids). The high level conceptual diagram of the of the logic structure OD Tool is described in Figure 3. The diagram shows the correspondence between the main functions.



Main Scenario created by David (December 12, 2001)

Figure 2: Automatically generated GETRAM model for the Problem Network defined by the graphic window

For edition, OD matrices are presented to the user using a spreadsheet. The user can change any value directly typing on the cell or can apply some basic transformation to one cell or more cells as increment/decrement by a factor or adding/subtracting a constants. The interactive generation of Local Traversal OD Matrices from the global OD matrices is the function required to provide the inputs to the AIMSUN microscopic model of the Problem Network under analysis. The main input to a route based traffic simulation model is a time dependent origin-destination matrix, each of which OD_i entries represents the number of trips between the corresponding Origin-destination pair for the selected time period i. Usually this information when available concerns the global model of the site being analysed, the WAYFLOW network in the case example of this paper. This is not usually the case when a Problem Network is selected, unless the Problem Network has been created in a previous phase and it local OD matrix, or traversal matrix in other words, has been saved in a database containing sets of Origin-Destination matrices. Therefore the SAS, in addition to such database has the capability to generate interactively such local matrices combining the versatility of its software architecture with

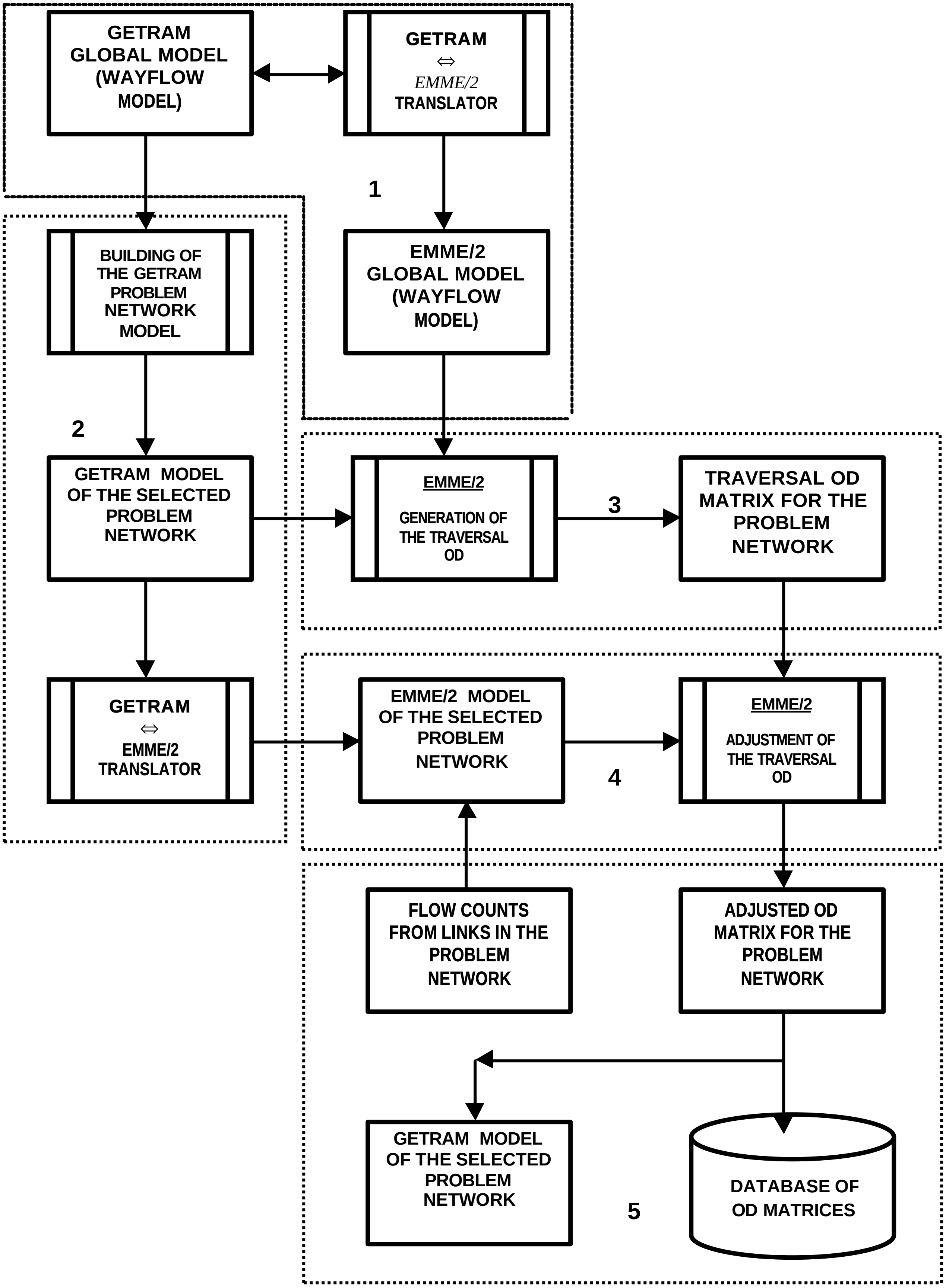
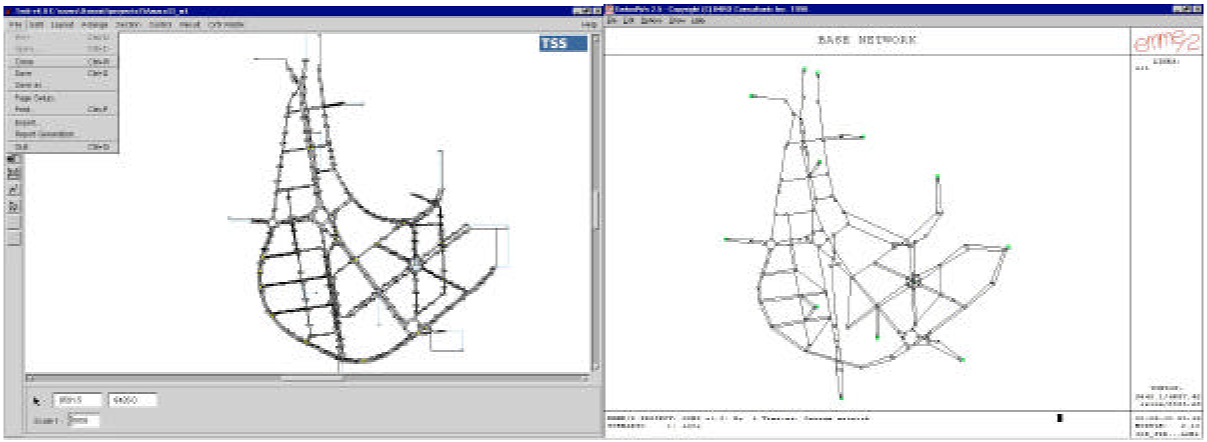


Figure 3. The conceptual structure of the ODTool and its main function

the computational power of the algorithms for traffic assignment and matrix calculations of the EMME/2 software.

The main functions of the OD tool as shown in correspondence with the blocks in Figure 3 are:

1. Automatic translation of the global network model for the site in terms of an EMME/2 model. If link flow counts are available for the time periods corresponding to the global OD matrices for the site, the translated EMME/2 model is prepared to automatically proceed to the adjustment of these OD matrix using the flow counts. An example of this automatic translation is depicted in figure 4. Figure 4a depicts the GETRAM model of a road network and the windows dialogue invoking the translation utility. The GETRAM model, corresponding to the high level representation of the road network required by the microscopic simulation, is translated in terms of the aggregated network representation proper of the transport planning models, the EMME/2 in this case. The translation ensures the consistency between both levels, micro and macro, of the road network representation.



(4a) (4b)

Figure 4: Translation from GETRAM to EMME/2

2. Automatic generation of the sub-network model for the Problem Network generated interactively in SAS, and its translation in terms of an EMME/2 model.
3. Automatic activation of the suite of programs to calculate the Local Traversal OD matrix for the Problem Network.
4. Automatic activation of the adjustment process of the Local Traversal on basis to the link flow counts for links in the Problem Network for the time period under consideration.
5. The adjusted Local Traversal is stored in the Database of OD matrices and exported to the AIMSUN model of the Problem Network as input data for the simulation of the selected scenario in SAS.

The estimation of time dependent OD matrices for dynamic analysis has so far efficient analytical solutions only for specific simple linear networks of motorway type, see for instance the Kalman filtering based approaches in (5, 6 and 7). The estimation of dynamic OD matrices for more complex road networks is still an open research topic. From a practical point of view what we propose is a heuristic approximate procedure based on empirical grounds, providing acceptable useful estimates. The heuristic is based on the following assumptions:

1. The network for which the time dependent OD matrix is to be estimated is a sub-network of a larger network for which an approximate time sliced OD matrix is known.
2. There are available traffic counts on a significant number of links of the selected sub-network for the time interval of interest.

The procedure consists of three main steps:

1. Starting from a global OD matrix for the whole region for a time horizon T (i.e. the whole day, the peak morning hour, etc.) use additional information on time distribution of trips to generate a set of OD matrices for smaller time intervals (i.e. for example for intervals of 30 minutes).
2. Let $\mathbf{OD_i}$ be the OD matrix for the i-th time interval, assuming that a scenario spanned by a sub-network of the global network has been selected, the next step extracts the Traversal $\mathbf{OD_i^T}$ for the selected scenario for the corresponding time interval, that is the sub-matrix of the global matrix for the selected sub-network.
3. Adjust the traversal $\mathbf{OD_i^T}$ from the observed flows for that time interval to estimate the matrix $\mathbf{\overline{OD}_i^T}$ that will be input to the AIMSUN microscopic model for the dynamic simulation.

3. TIME SLICING THE GLOBAL OD MATRIX

Figure 5 illustrates graphically the main concepts of this process. The graphics on the left corresponds to the typical view of a global OD matrix as used in traffic assignment. It represents a total number of trips over a time horizon T with an underlying homogeneous behavior. The graphic on the right represents the time variation of the demand. The total number of trips remains constant but they do not behave homogeneously. This representation corresponds to a discretization of the global OD matrix in which the time horizon T has been partitioned into smaller time intervals, and each component of the histogram corresponds to the number of trips for the corresponding interval.

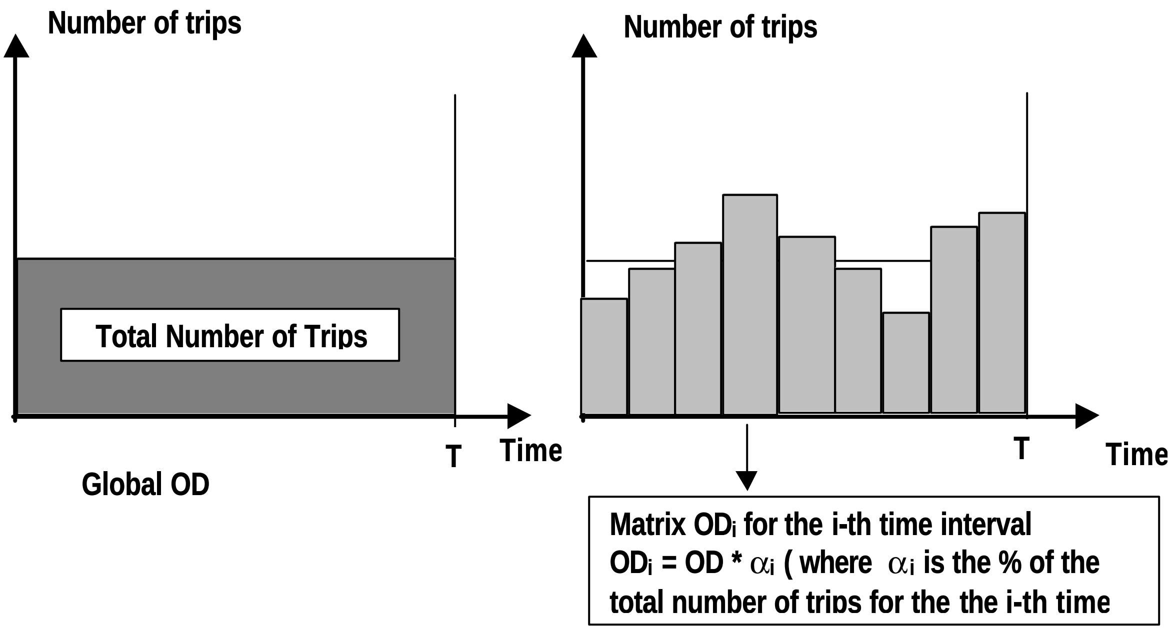


Figure 5. Time slicing a global OD matrix

4. Estimation of the traversal OD matrix for the selected scenario

To simulate the traffic flows on the sub-network corresponding to the selected scenario for the current period of time one of the basic data input required is the local OD matrix for the scenario for that period of time. That is the number of trips t_{ij} between each origin i, and each destination j for each time period. Origins and destinations could lay in the borders of the area spanned by the network, that is the input and output gates defined by the border of the sub-network, as well as in the area. This is the situation schematized in Figure 6 explained below.

Given an O/D matrix for the whole area and a sub-network, the proposed procedure starts by calculating the traversal O/D flows between gates defined by the border of the sub-network, that is it extracts from the global O/D matrix the sub-matrix corresponding to the selected sub-network. This sub-network defines the scenario selected by the operator, where the traffic conflicts have been identified.

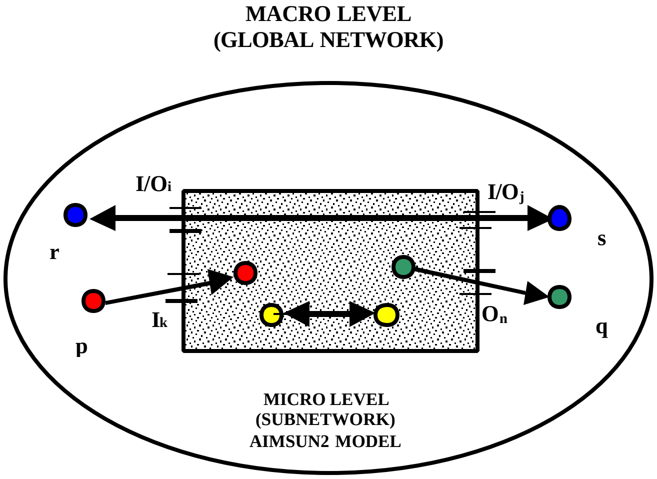


Figure 6: Traversal O/D matrix for a sub-area

This is illustrated graphically in figure 6. The so-called traversal matrix is the local O/D matrix for the shaded area inside the rectangle, spanned by a sub--network of the road network for the whole area. The traversal matrix is composed of the original Origins and Destination in the area plus some dummy origins and destinations, the input and output gates of flows into, from and through the area. In the figure I/O_i and I/O_j correspond to the i-th and j-th input/output gates, new dummy nodes, corresponding to the flows form centroid r to centroid s crossing the area, I_k is the k-th input gate for the flows with origin at centroid p, outside the area, finishing the trip inside the area, and O_n the n-th output gate, for flows generated at a centroid inside the area, leaving the area through this output gate and finishing the trip in centroid q outside the area.

The generation of traversal matrices is a standard procedure in EMME/2. Using the additional options auto assignment with its special **traversal operator** does the computation of a traversal matrix. First, the correspondence between gates and zones must be established. The links considered, as **in-gates** are all the outgoing connectors from the centroids located in the selected scenario, as well as all the links that enter the scenario boundaries. The links considered as **out-gates** are all the incoming connectors to the centroids located in the scenario, as well as all the links that exit the scenario boundaries. User data items (i.e. **ul3)** can be used to hold the gate information. For that purpose, it must be initialized to 0, and then prepared as follows:

- All centroid connectors within the scenario are defined as directional gates: all outgoing connectors, which have the centroid as I-node, are tagged with the positive centroid number (in-gates) and all the incom-ing connectors, which have the centroid as J-node, are tagged with the negative centroid number (out-gates). This can be done systematically by using the network calculator (Module 2.41).
- All the streets that cross the scenario boundary are assigned centroid numbers and are defined as directional gates, with the convention that if a street is two-way, the same centroid number is assigned to both corresponding links. All links which enter the scenario boundary are tagged with a positive centroid number (in-gates) and all links which exit the scenario boundary are tagged with a negative centroid number (out-gates). This can be done by using the graphic worksheet (Module 2.12), where the links crossing the scenario boundary can be identified easily.

The utilities implemented in SAS perform all these function automatically for the Problem Network under study after its graphic definition as described in the introductory section. The most important part are the function relative to the automatic identification and definition of the *gating system* for the GETRAM sub-network model of the Problem Network for its translation in the required terms of the EMME/2 traversal calculation mode. The function assumes that the basic input defining graphically a sub-network is a set of closed polygonal lines that define a connected area, as shown in the two examples in figure 7.

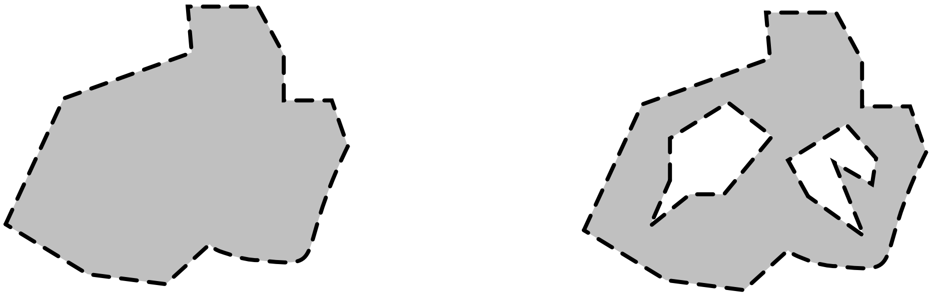
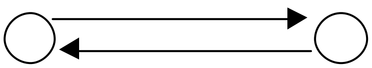


Figure 7: A connected Problem Network defined by a single polygonal line (left) and by several polygonal lines (right).

The elements making up the sub-network can then be derived just by identifying which *physical* nodes fall inside the Problem Network. The rules of the generation of the EMME/2 model of the Problem Network for the automatic calculation of the traversal OD matrix a, lustrated in figure 8, are the following:

1. The physical sections of the sub-network must be the physical sections of the global area that have their physical starting node and /or their physical ending node with coordinates lying in the interior of the region that defines the Problem Network. All the attributes of the sections in the sub-network are inherited from the corresponding ones in the global area.
2. The physical nodes of the sub-network model are those with coordinates lying in the Problem Network.
3. The physical sections of the sub-network that have starting node with coordinates in the Problem Network define an output of the sub-network. The physical sections of the sub-network that have ending node with coordinates in the Problem Network define an input of the sub-network. Inputs and outputs can gather forming a *gate* only if their physical sections were opposite in the global network model. (i.e. having common starting/ending nodes:



"Opposite sections or links"

4. Centroids of the global network model with at least a connector attached to a node with coordinates lying in the Problem Network correspond also to a single gate of the sub-network model. If all the connectors of the centroid have attachment points lying in the Problem Network then, the centroid must be considered as a *centroid fully interior* to the Problem Network. In this case the gate number matches the centroid number assigned to the centroid in the global area (see, in the figure, centroid 23). Otherwise, i.e. if there exist connectors with attachment not in the Problem Network, then the gate number can be other than the centroid number in the global area (see, in the figure centroid number 21, which corresponds to gate number 17 in the sub-network model).

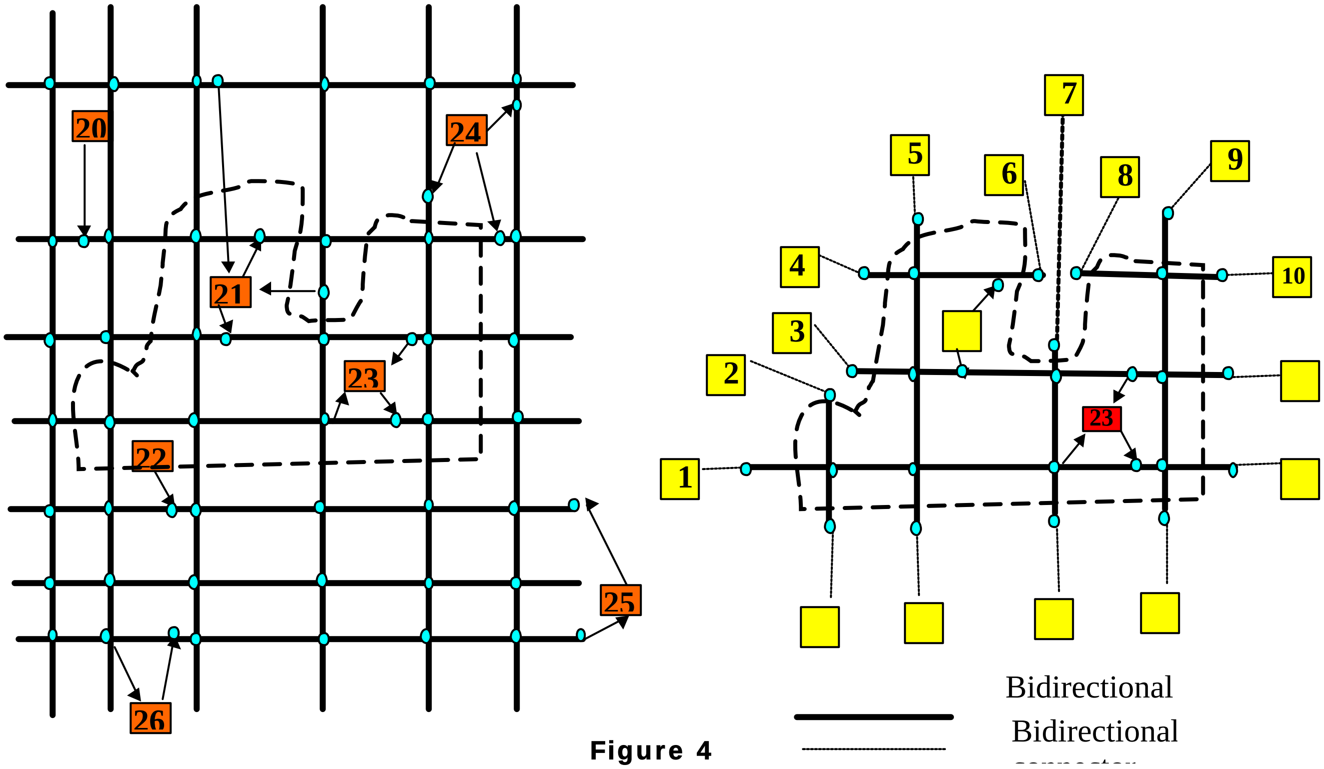


Figure 4

5. Gate numbers can be given arbitrarily to the gates of the sub-network, excluding the case of gates corresponding to *centroids fully interior* to the Problem Network, which must have gate number equal to the centroid number in the global area**.**
6. There can not be duplicates in numbering the gates of a sub-network model.
7. Gates are attached to the corresponding starting or ending nodes of physical sections by means of connectors. The connectors emerging or incoming to gates of the sub-network model.

5. Adjustment of the traversal matrix

The traversal matrix has been extracted from a global OD matrix whose information correspond to an average long term representation of trip patterns, therefore it could have significant deviations with respect to the actual trip patterns for the time interval under consideration. If information is available about the current traffic flows on the links of the sub-network, or at least on a significant number of links, then this information can be used to adjust the local OD matrix and get a better representation of the trip patterns.

The core of this heuristic is an adjustment method based on a bilevel optimization method. The algorithm can be viewed as calculating a sequence of O/D matrices that consecutively reduce the least squares error between traffic counts coming form detectors and traffic flows obtained by a traffic assignment. The calculation of the traversal matrix for a sub-area requires information about the routes used by the trips contained in the O/D matrix (d_{ij}). It requires the definition of the route and the trip proportions relative to the total trips d_{ij} used on each route originating at zone i and ending at zone j. This information is really difficult to handle and store in traffic databases, taking into account that the number of routes connecting all Origin-Destination pairs on a connected network can grow exponentially with the size of the network. This is the reason to use a mathematical programming approach based on a traffic assignment algorithm that is solved a each iteration without requiring the explicit route definition, that computes the traversal matrix during the network loading phase of the algorithm.

The implementation of the heuristic, which follows the methods proposed by Florian and Chen (8), Spiess (9), is based on the available interfaces between GETRAM/AIMSUN and EMME/2, and the utilities implemented in EMME/2 macros. Once the traversal is computed the adjustment can be done in a standard way using the EMME/2 macro **demadj.mac**, which is activated automatically by SAS. The adjusted matrix is then imported by SAS into AIMSUN through the corresponding dialogue**:** “Import from EMME/2” .

6. CONCLUDING REMARKS

The methodology described in this paper, which logical diagram has been illustrated in figure 2, has been successfully implemented and tested as part of the ISM (Intermodal Strategy Manager) project in Hessen, Germany, in the framework of the WAYFLOW Program.

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