

## **ADVANCED TRAFFIC CONTROL STRATEGIES IN MADRID**

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### **SUMMARY**

This paper presents the approach taken in project CAPITALS/MADRID for the design, implementation and demonstration, of a wide area traffic control system in which the controlled area is divided in several zones each one controlled by its own traffic control system. The paper describes the functional architecture of a Supervisor system which achieves the co-ordination between the local control systems through an information interchange, some predictive capabilities and the resort to a detailed microscopic simulation to estimate the short term evolution of the traffic conditions on the controlled area.

### **INTRODUCTION: PROJECT OUTLINE**

CAPITALS/MADRID is a project aimed at developing and demonstrating a prototype of an area wide adaptive interzone management centre, based on a supervisor reconciling, and co-ordinating through a negotiation process, the control strategies operating at various zones in the area of reference.

A current situation in most big metropolitan areas, as in the case of the chosen site in Madrid, is that, due to historical and technological reasons, different zones in the area are controlled by different and independent traffic control centres, operated by different traffic control systems based on different approaches, which apply different control and management strategies.

Usually these control systems are stand alone systems working only with the information supplied by traffic detectors on the controlled zone, and therefore having only a local view limited to the own zone and ignoring what is going on at other zones. This lack of communication between the systems leads to conflicting situations due to time varying demands at some zones which generates variations in flow exchanges between adjacent zones which cannot be easily handled by the local control because of its hysteresis in the process of changing the control and management strategies which are currently operating.

An example fitting this description is the test site chosen for the CAPITALS/MADRID project displayed schematically in figure 1. The site correspond to the area of Madrid's road and street network bounded by the Motorways M-30 and M-40, and the national roads N-V and N-401, identified as Zone II in the figure, and the additional urban area, identified as Zone I in the figure, which corresponds to the urban area controlled by SCOOT. There are several traffic control centres operating in this area:

- Zone I, the urban zone controlled either by SCOOT or by the multialgorithmic system MOT developed by SICE has its own Traffic Control Centre with its specific control strategies.

- Zone II is controlled by a conventional traffic control system based on libraries of fixed plans, and ad hoc management strategies operated from its own Traffic Control Centre
- The M-30 and M-40 motorways are managed by another Traffic Control Centre with ad hoc management strategies
- This also the case for the N-V, managed by another Traffic Control Centre

The approach taken in this project to avoid, or at least alleviate, the conflicts originated by the lack of co-ordination between the traffic control centres, is based on designing and building a Supervisor System with the following functions:

- To enable a dialogue and exchange of information between the various traffic control centres
- To co-ordinate the strategies at the different zones based on the information from each zone
- To make recommendations on changes and adaptations of the strategies at each zone based on the information on demand variations at other zones and estimates on variations in flow exchanges that they will cause.

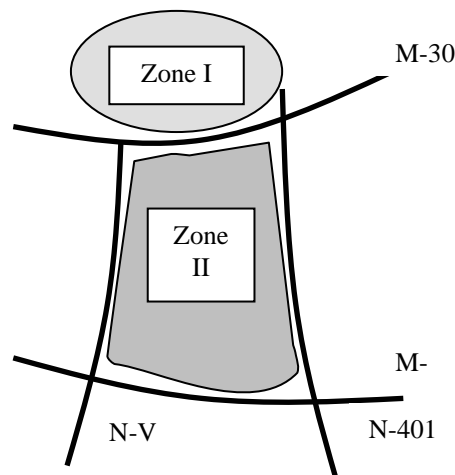


Figure 1. Schematic diagram of the Madrid Test Site

The local traffic control centres dialogue through the Supervisor exchanging information flows as follows: Each local control centre has a view of the current traffic conditions in the controlled zone provided by the traffic measurements supplied by the traffic detectors on the zone. This information is used by the system to determine at each instant, which is the control policy to apply according to the rules and strategies previously defined. The process of designing and building the proposed supervisor and co-ordinator system requires:

- A detailed analysis of the recurrent conflicts arising in the supervised scenario
- The identification of the co-ordination requirements: information flows between the control centres, operating conditions for the control centres, decision making mechanisms to select a strategy according to the user objectives, etc.
- The specification of the system co-ordinating functions according to the requirements, the information flows and the user objectives.

An additional highly recommendable feature for this class of systems is that of supporting the recommendations not only on the knowledge of the current situation but also on a short

term forecasting of how the traffic system can evolve in the immediate time horizon. This requires a proposal for such short term forecasting in the selected scenario.

### SUPERVISOR OVERVIEW

The figure 2 displays the functional architecture of the Supervisor system. The local Traffic Control Centres (TCC) send to the Supervisor aggregated traffic data measurements every  $\Delta t$  time units (design parameter), as well as the information on the traffic control plan currently operating in the zone controlled by this TCC. The Supervisor uses this information to evaluate the current Traffic State on each zone in the selected scenario. The traffic flow measurements on each zone, along with the historical information for that time period, provide the input to perform a short term forecasting of the evolution of Traffic State on the corresponding zone. The comparison between the current and forecasted traffic conditions on each zone are the basis to elaborate recommendations for the TCC's on how to adapt the corresponding traffic control plans to fit in the most suitable way the changes in the traffic demand in the time period considered.

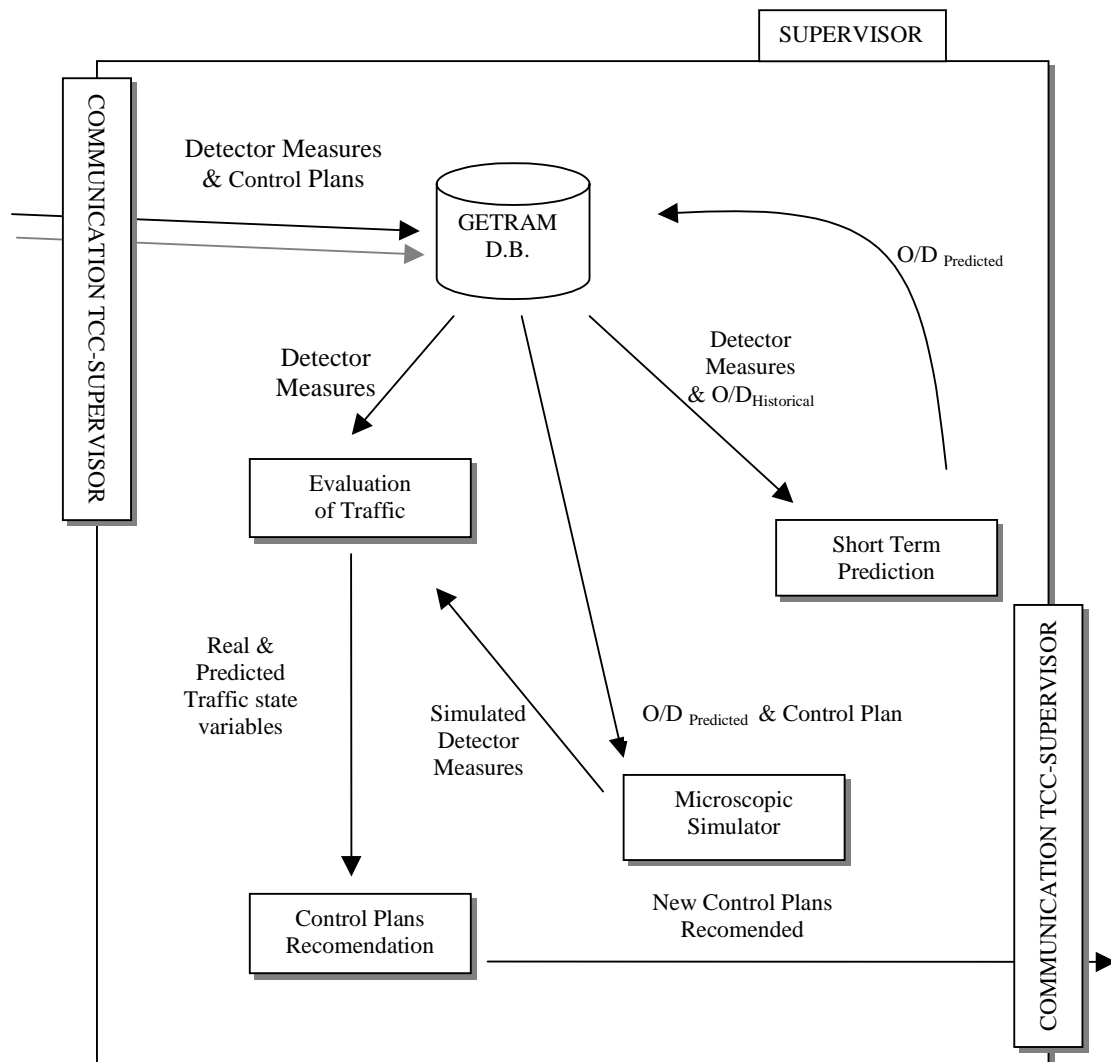


Figure 2: Functional Design of the Supervisor

The supervisor is composed of the following modules:

- **Getram Data Base:** A Traffic Network Database shared with the microscopic simulation model, stores all the information required to model the scenario on which the Supervisor will actuate, that is: information on the topological structure of the traffic network and on the specific traffic devices and information items, as for instance, traffic detectors, traffic control plans, turnings at junctions, ramp metering, Variable Message Signs (VMS), demand mobility patterns (O/D Matrices), etc.
- **Evaluation of Traffic States:** contains the traffic models and algorithms to estimate the traffic conditions on the network based both on detector measurements and on their emulation by the microscopic simulator.
- **Short Term Prediction:** based on a neural network model fed with flow measurements and historical information on mobility patterns estimates a forecasted O/D matrix which represents the expected evolution of the demand in the time period under consideration.
- **Microscopic Simulator:** a detailed microscopic simulation model whose inputs are the current conditions and the short term forecasted demand, which under the assumption of a do nothing scenario performs an estimation of the short term evolution of the traffic state on the network.
- **Control Plans Recommendation:** based on the estimated evolution of the traffic state on the network, and a decision support model relating traffic states and traffic control plans, recommends the changes most suited to the expected evolution.
- **Communication Module:** interfaces the supervisor with the TCC managing the information flows from TCC 's to the Supervisor and reciprocally. The TCC 's send to the Supervisor every  $\Delta t$  time units, a system parameter which value is determined by the operator, the aggregated traffic data (flows, speeds, occupancies, etc.) measured by each detector, and the data of the traffic control plan currently active. The supervisor sends to each TCC the recommendations on the control plan most suited to the expected conditions.

The decision support model that constitutes the Recommendation Module is based on a decision table, which relates traffic indicators on each zone to the traffic control plans. To define such a decision table relating the identified recurrent conflicts with the strategies on each zone of the selected scenario, or combinations of strategies in the various zones comprised in the scenario, a set of detailed simulation experiments has been designed and conducted. The main reason for that is that in practice not all potential combinations of strategies have been tested given the high social costs of these class of experiments, costs that can be avoided by resorting to simulation.

In a first phase a study has been conducted in Zone I, to check the feasibility of the process and establish the methodological patterns for the whole scenario. A vast data collection process was undertaken to collect information on: Flows, saturation indices, mean observed delays, average speed in the zone, average number of vehicle stops, etc. These data have been collected for sample days or each working control strategy for the corresponding day. In the case of Zone I that means:

A) Zone I controlled by a library of fixed plans:

Strategy n:

<b>Time period</b>	<b>1</b>	<b>2</b>	<b>.....</b>	<b>.....</b>	<b>m</b>
Fixed Plan	#i	#j	.....	.....	#k

A detailed data collection process for each combination has been carried out.

#### B) Zone I controlled by SCOOT.

The combinations of values of parameters determining the SCOOT working conditions provide a set of alternative strategies based on the use of SCOOT. The same set of data as before has been collected for each of these strategies.

The result of the data collection process has been a wide set of observations of the states of the road network, for the same demand, under various control strategies. These data have been the basis for calibrating a simulation model of the zone and complete the observations by simulating other feasible alternatives. Similar sets of simulation experiments have been designed and conducted for the other zones, completing in that way the set of decision tables.

The logic of the Supervisor process and the functional diagram of the relationships between the Supervisor and each TCC, as displayed in Figure 3, is the following

- Every  $\Delta t$  time units the Supervisor receives from each TCC the measured traffic data on the zone under the scope of the TCC, and the information concerning the current traffic control plan.
- The Evaluation Module of the supervisor uses the traffic measurements to evaluate the prevailing traffic conditions.
- The Short Term Prediction module combines the detector measurements, the historical information and the information on the current traffic control plans to perform the short term forecasting of the mobility matrix.
- Detector measures and forecasted O/D matrix feed the Microscopic Simulation Model of the traffic network of the zone, which simulates the evolution of the traffic conditions in the zone for the forecasted time period.
- The simulation output feeds the Evaluation Module, which evaluates the traffic conditions for the forecasted period.
- The evaluated prevailing traffic conditions and forecasted traffic conditions are input into the Recommendations Module which sets up the set of recommended actions for each zone and informs the corresponding TCC.

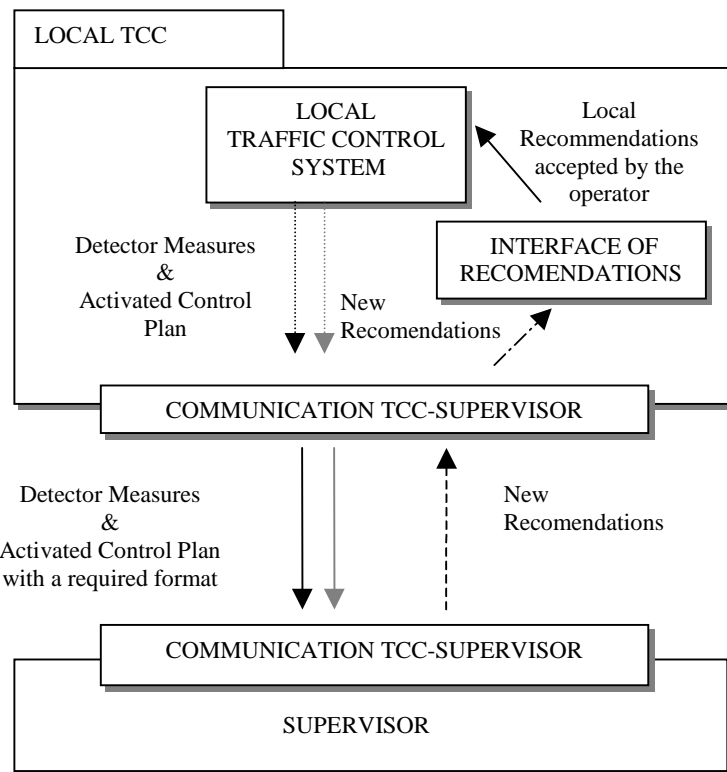


Figure 3. Functional relationships between the Supervisor and the TCC ' s

This architecture of the supervisor is based on the framework for Traffic Management Systems proposed in (1), and the realizations of such framework as experienced in the project PETRI (2), of the EU Programme ESPRIT.

### THE SIMULATION APPROACH USED IN CAPITALS/MADRID

The Selected Simulation Tool for CAPITALS project in Madrid is AIMSUN2 (3), (4) and a software tool based on a microscopic simulation approach capable to reproduce the real traffic conditions on an urban network, which may content both expressways and arterial routes. The behaviour of each single vehicle which is on the network is continuously modelled throughout the simulation time, according to several driver behaviour models (car following, lane changing, gap acceptance). AIMSUN2 is a combined discrete-continuous simulator: there are some elements of the transportation system (vehicles, detectors) whose state change continuously over the simulated time period, while there are other elements (traffic lights, entrance points) with state that changes discretely at specific points during the simulation time. It provides a very detailed modelling of the traffic network: it distinguishes between different types of vehicles and drivers; it permits to deal with a wide range of network geometries; it can also model incidents, conflicting manoeuvres, etc.

Microscopic simulation models are specially suited to reproduce accurately actual traffic conditions on road networks on a computer, this feature makes microscopic simulators the most suitable tool for assessing the effects of RTI systems. Microscopic models consist basically of two main components, an accurate description of the road network geometry including traffic facilities as traffic lights, traffic detectors, Variable Message Sign Panels, etc.; and a very detailed modelling of traffic behaviour which reproduces the dynamics of

each individual vehicle, distinguishing between different types of vehicles, with the possibility of taking into account behavioural aspects of vehicle's drivers.

Microscopic simulation models are the ones closer to reality in the reproduction of the traffic system opening a wide range of traffic scenarii in which precise descriptions of traffic control and traffic management schemes can be explicitly included. Cars behaviour is simulated on a car by car basis, according to leader-follower and lane change models.

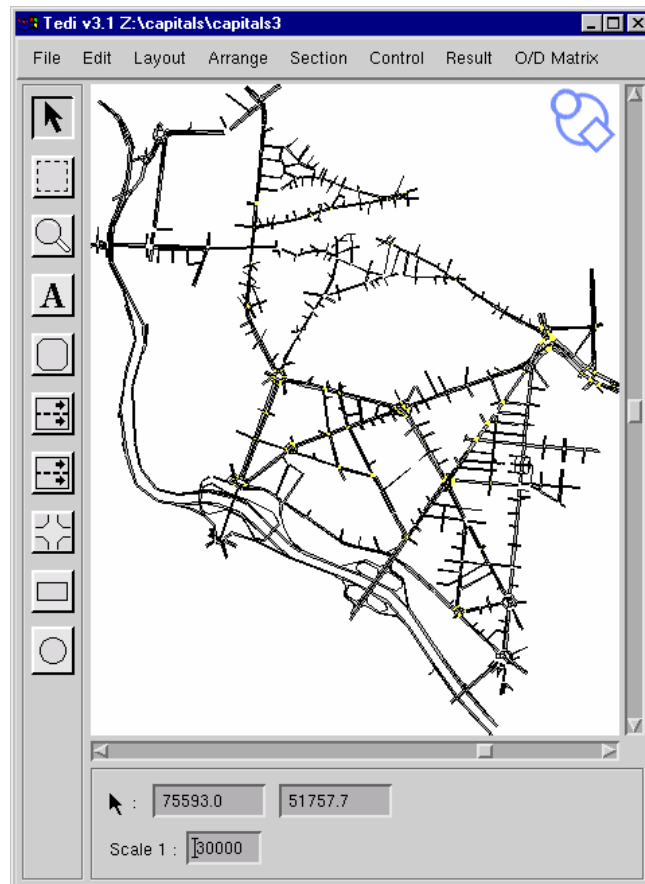


Figure 4: AIMSUN2 simulation model for Zone I in CAPITALS/MADRID

Non-linear Car-following models postulate more complex relationships for a more realistic description of car's behaviour and that asks for more parameters whose values have also to be empirically estimated. Empirical models like the ones proposed by Gipps, (6), (7) based on the assumption that each driver sets limits to his desired braking and acceleration rates, provide more realistic results.

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 duration, for signal controlled junctions, the priority definition for unsignalized junctions and any required ramp-metering information. The necessary inputs for the simulator are the traffic volumes at the input sections, the turning proportions at junctions and the initial state of the network. The output provided by AIMSUN2 includes a continuously 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).

AIMSUN2 is integrated into the GETRAM simulation environment (8), (9), which consists of a user-friendly graphic interface, a traffic network graphic editor supporting any kind of road network geometries, urban and non-urban, interfaces with traffic assignment models, a network database, and modules for storing, analysing and presenting results including the animated simulation output. A set of high level object-based programming functions provides the support for integrating a new simulation models within the environment, accessing any class of data, and manipulating the objects in the network representation.

For simulations based on flows generated at origins with specific destinations in the network (5), AIMSUN2 includes a shortest route computation module which uses link costs in terms of the current link travel times estimated during the current time period. A route choice model with several alternatives assigns vehicles dynamically to these routes at each simulation time slice.

A detailed AIMSUN2 model of the proposed CAPITALS/MADRID scenario has been built, and the simulation experiments have been conducted according to the methodology described at the end of section 1. Figure 4 displays a snapshot of Zone I model.

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