

## JUNCTION MODELLING IN EMME/2

IAN TAYLOR & PETER WILLOUGHBY, OSCAR FABER, UNITED KINGDOM

### 1. INTRODUCTION

EMME/2 has been used for highway modelling in the UK for about nine years within Oscar Faber (formerly Transportation Planning Associates, TPA) it has been used in a wide range of studies for both urban and inter-urban traffic models.

Our experience shows that it is a valuable tool for strategic studies, however, for the urban situation EMME/2 has been let down by its lack of an inbuilt junction delay model. The main emphasis of model building at the current time has been on urban area multi-modal models. These have been used to consider the impacts on travel making of public transport priority routes and the development of corridor strategies to improve travel opportunities and the on street environment through a wide range of measures. Critical in all these studies is the investigation of the impact of traffic congestion both now and in the future in the study area. This inevitably leads to an examination of traffic control and junction performance.

This paper considers why it is important that EMME/2 should have the facility for junction modelling. We then discuss the various approaches that have been undertaken within Oscar Faber in an attempt to satisfy this requirement. Two separate external software packages are described.

We then consider what could be achieved using a macro based approach utilising the turn penalty functions available in the current release of EMME/2. Although an initial attempt has been made to set up macros to model junction delay, this paper is essentially intended to promote discussion into the wider need for junction modelling in the EMME/2 community and to identify means by which this may be achieved.

We conclude that although significant steps can be taken by using macros and that interfacing EMME/2 with third party modelling software is feasible, EMME/2 as it stands can never fully comply with the demands of urban traffic modelling in the UK context.

### 2. WHY DO WE NEED JUNCTION MODELLING ?

The urban area in the UK is characterised by congested streets and junctions in the peak periods. Consequently, to successfully model this situation it is crucial to reliably model the observed delays.

One of the main sources of delay in urban road networks is the higher frequency of road junctions which is sometimes compounded by interaction between junctions. Such junctions control the capacity of the road system and govern journey times and routes taken by drivers. The Department of the Environment, Transport and the Regions (DETR) issued the revised Manual of Traffic Appraisal in Urban Areas in May 1996. In the chapter discussing the appropriate modelling tools for urban studies it specifically states:

*As a minimum (the traffic modelling package) should be able to model the operation of both road junctions and the road links between them, so a realistic assessment can be made of delays and travel times over the full range of traffic flows encountered."*

---

This requirement is expanded to identify the major desirable characteristics for an urban modelling package. These include:

- estimation of capacities, queue lengths and delays at road junctions ( with values for individual turning movements being estimated separately for maximum realism):
- the ability to distinguish between junction types ( eg to allow U-turns at roundabouts but not at signalised junctions or priority junctions);
- realistic treatment of “blocking back” where queues at a junction affect the operation of upstream junctions.

The major alternatives to EMME/2 in the UK market, namely CONTRAM, TRIPS and SATURN, achieve this by explicitly modelling junction delay. SATURN employs a sophisticated simulation model, which takes into account interaction with neighbouring intersections, gap acceptance formulae, and conflicting movements to calculate delay for each turning movement, these delays are then fed into an assignment to produce a new set of flows. Assignment and junction simulation are iterated until the flows converge.

Recent studies undertaken by Oscar Faber have included the examination of bus priority strategies in a number of UK towns. For example a study completed this year was a multi-modal car-bus model considering a congested urban corridor. Options under consideration were segregated bus ways and bus priority at signalised junctions. The model was used to estimate the effect of transfer from car to bus of a number of strategies. Such a study, with its dependence on being able to model the impacts of junction delays on private and public transport is currently beyond the scope of EMME/2 without significant work having to be done in macro development..

Clearly this raises the question of whether we should use the appropriate model for each situation and accept that EMME/2 is not always the best tool for the job, or should we attempt to make EMME/2 an all purpose package that can take on any project. All four packages CONTRAM, TRIPS, SATURN and EMME/2 have their strengths and weaknesses, no one suite can claim to be the best choice in all cases. However, the lack of a junction modelling facility might relegate EMME/2 to a fourth best in many situations in the current environment in the UK. Therefore it has long been considered that for EMME/2 to be widely recognised within the UK market it must include a junction delay element in the assignment process. This paper reviews the various approaches that have been tried within Oscar Faber to achieve this.

### **3. PREVIOUS APPROACHES**

Junction modelling can be carried out by a number of methods which, in order of increasing sophistication, can be categorised as;

- implicit in link speed flow relationships ( ie the junction capacity is reflected in the link capacity);
- fixed turn penalties;
- flow dependent capacities with explicit delay and queue calculations; and
- as above, but with the addition of junction interactions.

EMME/2, as it is currently configured, is capable of implementing the two lowest level

---

approaches and also a simple turn delay relationship based on the flow making the turn. More complex approaches would require the development of macros..

The approach that we have adopted most frequently to date is to use speed flow relationships that allow for some element of junction delay. In particular the speed flow curves used in DETR's cost benefit analysis program COBA10 have been frequently used in EMME/2 applications. The urban speed flow functions developed for COBA10 are designed to take account of junction delay, however. they can at best model only the average delay over a length of highway containing a number of junctions.

In the past two research projects have been undertaken with the objective of developing a junction modelling capability for EMME/2. Both have been centred around free standing external software which have required the output of flows from EMME/2, external processing of the data and re-input to EMME/2 for further assignment.

These approaches have gone under the titles EMMEDY and EMandS and are described briefly below.

### **3.1 EMMEDY**

EMMEDY (EMME/2-DELAY) was developed by Oscar Faber (TPA) in 1990. Essentially it was a free standing program which emulated the Department of Transport programs PICADY and OSCADY. PICADY forecasts queues and delays at priority intersections whilst OSCADY carries out the same process for signalised intersections.

The EMMEDY process was controlled in DOS by a batch file which carried out the following processes:

1. Ran an assignment macro in EMME/2 to produce a set of flows.
2. Batched out turning flows at relevant junctions.
3. Ran the EMMEDY program which read the turning flows, calculated the delays and output a set of turn penalties.
4. Batched the turn penalties back into EMME/2 using a second macro.
5. Reassigned the traffic within EMME/2.

This process was repeated a controlled number of times, and tests for convergence could be made by storing assignments from previous iterations in link user data items. The EMMEDY program updated the D231.IN file each time to transfer delay penalties back to the EMME/2 assignment.

This process was developed for versions 4 and 5 of EMME/2, within which the facility for storing data relating to turning movements was limited and turn data items were not fully integrated with the function calculator. In particular the elements of the assignment that could be accessed by the turn penalty functions were very limited.

It was not possible to include delays and queues within EMME/2 listing or plotted output. Interface programs were also required to reformat the files for input to EMMEDY and EMME/2 and as subsequent versions of EMME/2 were released these formats changed leading to the need to update the package. Each junction was treated as free standing and no account could be taken of junction interaction.

### **3.2 EMandS**

In 1991 Oscar Faber initiated the development of the EmandS (EMME/2 and SATURN) package. This is a sophisticated suite of purpose built tools consisting of a number of

---

programs and DOS batch files which link version 5 of EMME/2 with version 8.3 of SATURN. This allows the multi-modal modelling and graphical capabilities of EMME/2 to be combined with SATURN's detailed simulation of highway junction operation.

The whole process is controlled by a DOS batch file that comprises of an assignment simulation loop covering:

- an assignment phase within EMME/2;
- the transfer of assignment results to SATURN;
- a SATURN simulation phase may the SATSIM module; and
- the simulation results transferred back to EMME/2.

The basic philosophy behind the process was to allow a set of link flows from a fully converged EMME/2 assignment to be used as the flow input to the junction simulation module SATSIM. The time/flow curves output by SATSIM would then be translated into turn delay functions for EMME/2. At the time of development SATSIM was a free standing junction simulation program within the SATURN suite. It is now a module called by the SATURN and SATALL processes.

Setting up the process requires the network to be held in both EMME/2 and SATURN formats. The process includes a program for translating the basic link data between the two packages. SATURN data coding requires a full description of each junction to be included which includes junction type, and for each approach the number of lanes making each turn, an estimate of the capacity available for each turn, indication of opposed movements and details of traffic signal timings where appropriate.

Once an assignment has been completed various calculations, stored within the SATURN files can be transferred to the EMME/2 databank to be plotted. These include queues on links, arrival and demand flows, link capacities and delays.

The process enables the EMME/2 user to gain access to most of the detailed junction simulation processes offered within SATURN. The advantage of using EMandS over SATURN is the enhanced graphical and matrix manipulation facilities within EMME/2 along with the opportunity to integrate the highway model with a public transport model within EMME/2. Although since the development of EMandS the graphics capabilities of SATURN have been considerably enhanced, EMME/2 probably remains the stronger package in this respect. In terms of mode split and public transport modelling, EMME/2 is amongst the best programs currently available .

The outcome of the process is a very powerful package. The suite was subjected to a rigorous testing which compared the results of carrying out assignments using a standard SATURN model with the results from an EMandS assignment. The tests were carried out using the networks and trip matrices developed previously for a study of a highly congested urban network. The validation process showed that the link flows output by EMandS and SATURN were sufficiently similar to agree within the tolerance limits laid out by the Department of Transport for model validation purposes. A study of journey times on major routes through the network also indicated a high degree of agreement between EMandS and SATURN.

The process is, however, unwieldy. It requires the batching out of data from EMME/2, reformatting this data for SATSIM and then a similar sequence of data transforms to re-input information to EMME/2. During testing of the model it was found that run times for an EMandS model could be up to three times that for running the same model in SATURN. The limitations on the numbers of data items that could be stored on links and turns at the time of the

---

development of EmandS contributed to this slow run time. It was necessary to pack large amounts of information into a few variables. The recent releases of EMME/2 have added considerably to the data storage within the EMME/2 databank and consequently a revised version of EmandS would be more efficient improving run times and leading to a more simple interface.

The suite is particularly susceptible to the frequent issues of new versions of both EMME/2 and SATURN, both of which required modifications to a number of EMandS programs to take account of changes in data file formats. Also critical is the necessity for users to hold licences for both EMME/2 and SATURN which leads to start up costs being very high for new users. Although the package has been used successfully in house, it is not currently being marketed.

The EMandS documentation states that "from an analytical point of view, and EMandS model is no more than the sum of its EMME/2 and SATURN components." In fact, for simple highway modelling there is little benefit to be gained in using EMandS over SATURN other than its superior graphical presentation of results and this can be achieved independently of the assignments by using the add on tools which convert assigned SATURN models to EMME/2 format. However, when considering using the highway model as part of a more complex multi-modal study the value of incorporating junction delay from EMandS is significantly greater.

EMandS remains a powerful tool for incorporating the acknowledged supremacy of the SATSIM package within the EMME/2 suite and fulfills all the requirements of an urban traffic model. Further development would be required to take advantage of recent developments in EMME/2 and to ensure compatibility with the most recent releases of both EMME/2 and SATURN.

---

## 4. A MACRO BASED APPROACH

Since the development of EmandS, EMME/2 has gone through two further upgrades, versions 7 and 8. One of the main features of Release 7 was the possibility to access turn attributes in the network calculator. New turn attributes were introduced which included auto volumes on turns (pvolau and pvolad), turn penalty function index, and user data items for turns.

At the same time the range of data accessible for a given link was greatly enhanced giving access to the outgoing link and K node attributes for a given node. For the first time it became theoretically possible to develop macros that could carry out some of the functions that EMMEDY and EmandS were designed for within EMME/2 and to include these within the assignment process.

The introduction in Release 8 of the graphical interface for editing turn data has also greatly improved the users scope for examining and modifying turn data items.

The process was simplified by the introduction in Release 7 of the generalised cost auto assignment. The majority of models developed in the UK are validated on the basis of route choice through a generalised cost based on a linear function of time and distance costs. Prior to Release 7 these were calculated by substituting generalised cost for journey time in the speed flow relationships. As a result of Release 7 the speed flow functions could be modified to produce true journey times and consequently turn penalties could be included as actual delays rather than generalised cost delays as previously.

A number of macros illustrating the power of these functions have been developed and circulated by Heinz Speiss. These included the OPPVOL macro which calculated the opposing volume for a given turn, and which has formed the basis for this study of junction delay macros.

It is probable that in the short term the development of assignment macros involving a calculation of junction delay would enable EMME/2 assignments to take some, albeit rudimentary account of junction delays. To the author's knowledge, this has not been successfully implemented to date. This chapter reviews the processes that would need to be considered in developing a junction modelling version of EMME/2 and describes the early stages of a prototype junction delay macro.

### 4.1 Considerations

Junction simulation and the application of queueing and delay formulae can be considered in two distinct categories which may be called 'high definition' and 'low definition' respectively. In the former the flow and capacity information required to predict queues and delays are defined on a short time scale ( eg successive one minute or five minute time slices) and through this it is possible to predict in detail the time variation of the average queue length and vehicular delay. In the latter, the flow and capacity information are defined on a longer time scale ( typically 30 minutes to an hour) and it is only possible to predict overall quantities such as the average queue length over a long period or the average delay per vehicle evaluated over a complete peak.

Traffic assignment and simulation models attempt to balance the vast data requirements of the former without the loss of accuracy of the latter by either modelling a sequence of time slices and passing end of slice queues from one assignment to the next, or by entering an approximated profile of traffic arrivals over the modelled period to the junction model.

The key elements to consider in developing a fully fledged model of either form, capable of

---

modelling junctions within EMME/2 would be;

- delay formulae for each junction type
- modelling the impacts of delays and traffic platooning at neighbouring junctions;
- creating an iterative process to alternate between assignment and junction simulation which would need to monitor the convergence of the process and to introduce volume averaging between successive assignments to ensure that traffic did not continually switch between two competing routes as a result of modifying junction delay.

The impact of neighbouring junctions is most critical in the modelling of city centre environments, where a large number of critical intersections can be situated in close proximity. It is considered that this is currently beyond the scope of being incorporated within an EMME/2 macro since this would require some form of simulation model to be integrated with the assignment. Consequently the development so far has concentrated on the development of junction delay macros and the control of the assignment process.

## 4.2 Current Developments

The author is currently developing a set of macros capable of carrying out an iterative assignment and simulation process that will calculate junction delay at each step and include this in the next iteration. This is at an early stage and at the time of writing delay formulations have been considered only for priority junctions. The work has been based on the low definition approach given in Kimber and Hollis (1979). The nature of the EMME/2 assignment process dictates that these should be of the low definition form.

Capacities are defined separately for opposed left and right turns and for unopposed turns. It is necessary to include in the network coding an indication of whether each turn has priority or gives way to other traffic. Left and right turns are determined using the formula given in EMME/2 News May 1994 page 9. Additional network coding necessary to implement this process is an estimate of the capacity for each turn. This is coded as a turn data item. A modified version of the OPPVOL macro is used to determine opposing flows for each turn.

At the time of writing the macro is still under development, the basic code has been written and tested. However, the announcement in the recent issue of EMME/2 News indicates that further relevant enhancements to EMME/2 will be made in Release 9 which will be available in Spring 1998. These include the incorporation of additional turn attributes in the auto assignment module and the increase in the number of function parameters allowed in the turn penalty functions. Consequently development of the macro has been temporarily suspended to avoid work in developing macros to handle data packing and manipulation that might be unnecessary when the more powerful version of EMME/2 becomes available.

It is intended to extend the macro to include a calculation of queue length. The completed process would then enable assignments to take account of delays at junctions in calculating least cost routes through the network, and once the assignment process was complete plots would be available of average delays and queue lengths on each link.

## 4.3 SUMMARY

INRO have input considerable effort to enhancing the turn calculator and turn penalty functions in recent releases on EMME/2. This will continue into Release 9. In our view, when combined with the increased capabilities of the macro programming language, junction delay functions can be implemented within EMME/2.

---

Despite this, it is unlikely that a model capable of fully representing junction interactions can be produced without linking EMME/2 with a junction simulation model. At best the macro approach can introduce an additional level of detail into a model where junction delays are central to the study.

## 5. CONCLUSION

The author considers that the need for an element of junction modelling is critical for EMME/2. The EmandS program has been tried and tested and demonstrated to be a highly effective tool for incorporating a sophisticated simulation tool within the assignment process for EMME/2. Testing demonstrated that the package produced results comparable with SATURN in a congested network assignment.

Major problems exist however with the development of EmandS. It depends on the inclusion of a module from a competing software suite. A suite that is constantly being modified and upgraded. EmandS was developed as a suite of programs to reformat data to facilitate the transfer between EMME/2 and SATURN. As each new upgrade to either suite is made a rewrite of sections of EmandS would potentially become necessary. The alternative would be to fix on a particular release of SATSIM, which demonstrably fulfills the modelling requirements of EmandS and ignore SATURN upgrades. This in turn would have drawbacks if the manufacturer of SATURN withdrew support for this release at any time. Any use of EmandS relies upon the continued cooperation of the distributors of this particular piece of software and assumes that potential users hold licences for both EMME/2 and SATURN.

A more promising approach is the development within EMME/2 of macros to reproduce some of the calculations carried out within SATSIM. The complexity of junction interaction is probably beyond the scope of EMME/2 at the current time, however, it would not be difficult to develop a suite of macros to handle the basic junction delay formulae and to include these within an assignment process. This would enable EMME/2 to be used as a tool to study the impacts of junction improvements and to include junction delays within public transport assignments. The author would be interested to receive details of examples where such macros have been attempted by other users, and intends to progress the development of the approach outlined in this paper to create a set of macros capable of modelling a simple urban area.

A problem with the development of any form of junction based modelling is that EMME/2 is aimed at a world wide market. Junction control varies widely in different countries and the formulae derived for use in the UK may not be suitable for other users. Any inbuilt junction modules would have to be general enough to recognise this which, in turn, may leave them insufficiently detailed for specific applications.

In the long term it is unlikely that software modifications can ever be made to EMME/2 itself to fully satisfy the need for junction modelling. We acknowledge that such developments would require significant changes to the foundations of the EMME/2 model. The more appropriate path would be to further investigate tying EMME/2 in with a simulation package, possibly giving consideration to the new generation of microscopic simulation software such as PARAMICS and AIMSUN2.

## 6. Bibliography.

Kimber R M and E M Hollis (1979) Traffic Queues and Delays at Road Junctions. Transport and

---

Road Research Laboratory Report LR909.

Highways Agency(1996) Design Manual for Roads and Bridges Volume 12a. Traffic Appraisal of Roads Schemes

*The authors may be contacted via Oscar Faber, Marlborough House, Upper Marlborough Road, St Albans, Hertfordshire AL1 3UT, tel: +44 181 784 5784, fax: +44 181 784 5700.*