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Appraisal of Eight Small Area Traffic Management Models

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ABSTRACT

In this paper eight small area traffic management packages or models are selected for appraisal. These models are useful for predicting the impact of traffic control measures before implementation. These measures include street closure, turn bans, priority junctions, one-way street systems, traffic signals and roundabouts. Packages for freeway analysis are not included in this study. The criteria adopted in the appraisal are the level of detail, possible applications and validations, assignment algorithms adopted, computational requirements and documentation. SATURN was found to be an 'all rounder' with a theoretically sound assignment method, an accurate simulation of traffic progression and the capacity for modelling a variety of control measures. However, an overseas model such as SATURN has built-in parameters which may not be suitable for local Australian traffic operations. Traffic models suitable for local conditions should therefore be considered wherever appropriate.

INTRODUCTION

It is recognised that area-wide traffic management schemes should be designed to achieve a balance between efficient traffic along arterial roads and protection of the quality of the environment of adjacent local streets. However, analytical tools are not yet available to predict with sufficient accuracy, for example, the intrusion of through traffic into local streets due to signal control measures or right turn bans on arterial roads. There is, therefore, a need to provide analytical tools that are sensitive and accurate in predicting and assessing the short- and long- term impacts of traffic management measures on an arterial road/local street network.

A number of traffic management computer packages are currently reported in the literature. These packages are useful for predicting the impact of various management or control measures in a study area before they are implemented. Eight such packages are selected for appraisal in this paper. Packages for freeway studies are excluded. To a varying degree, these small area study tools claim to be:

(a) of sufficient detail for short-term planning and design of arterial roads or local areas;

(b) previously validated on real-world networks;

(c) with current program support;

(d) suitable for both open network geometry (e.g. arterial roads) and closed network geometry (e.g. central business districts (CBD)); and

(e) capable of analysing most, if not all, of the effects of a variety of measures including:

- (i) street closure;
- (ii) turn bans;
- (iii) priority junctions (that involve major/minor intersections controlled by Stop/Give-Way signs);
- (iv) one-way street systems;
- (v) traffic signals (either fixed-time, or vehicle-actuated (VA), or both);
- (vi) isolated or co-ordinated signal control; and
- (vii) roundabouts.

Table I summarises the authorship and availability of the eight packages selected for appraisal. Packages 1 to 5 have a traffic assignment procedure to study the routeing of vehicles in a network for a given origin-destination (O-D) trip matrix. They are suitable for studying the route diversion effect of a traffic control measure. Packages 6 to 8, on the other hand, do not have the capability of assignment. They require the user to supply the flow levels and the direction of each traffic stream at an intersection (i.e. traffic counts). These last four models are suitable for studies in which re-routeing can be ignored. They would be useful for predicting short-term impacts by comparing the traffic conditions before, and after, a control measure is implemented. Mention

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TABLE I

THE EIGHT TRAFFIC MANAGEMENT MODELS

Package	Authorship/references*	Country of Origin
1. CONTRAM	Leonard, Tough and Baguley (1978) Tough (1978) Leonard and Tough (1979) Leonard and Ogden (1982)	UK
2. LATM	Taylor (1977, 1978, 1979*a* and *b*, 1980, 1982) Taylor and Gipps (1982)	Australia
3. MICRO-ASSIGNMENT	Brown and Scott (1970) Easa, Yeh and May (1980*a* and *b*) Easa and May (1981)	USA
4. SATURN	Bolland, Hall, Van Vliet and Willumsen (1977, 1979) Bolland, Hall and Van Vliet (1979) Willumsen (1978) Ferreira, Hall and Van Vliet (1981,1982)	UK
5. TRANSIGN	Nguyen and James (1975) Charlesworth (1977, 1978, 1979, 1980)	UK
6. NETSIM†	Lieberman, Worrall, Wicks and Woo (1977*a*,*b*,*c*,*d*, and *e*) Lieberman (1981)	USA
7. TRAFFICQ	Logie (1977, 1979*a* and *b*, 1982) Dawson (1979) Logie and Dawson (1980)	UK
8. TRANSYT/8	Robertson (1969) Robertson and Vincent (1975) Hunt and Kennedy (1980) Vincent, Mitchell and Robertson (1980)	UK

* Only major references are included.

† NETSIM is now a component within the TRAF simulation system which will soon be available from the U.S. Federal Highway Administration.

should be made of the arterial road simulation package MULTSIM (Gipps and Wilson 1980; Gipps 1982), which provides a detailed modelling of car-following, lane-switching, vehicle acceleration and deceleration characteristics. It is, however, only suitable for modelling one-way traffic and is not thus included in the appraisal.

This paper is concerned with the comparison of various features of each package in order to select those most appropriate for further investigation. A detailed description of each package is beyond the scope of this paper. Readers are referred to the publications shown in *Table I* for further information. It should be noted that the selection of packages is not exhaustive, and only those that are widely publicised and supported are included in this Table. Apart from NETSIM and TRANSYT/8, the other programs have not yet been implemented by the authors on a computer for testing. The appraisal is based on a review of the published material, and is therefore largely subjective.

THE COMPUTER PACKAGES

CLASSIFICATION OF MODELLING TECHNIQUES

There is a wide spectrum of modelling techniques available in developing traffic management packages. For convenience, the techniques adopted in the models shown in *Table I* are broadly grouped into three categories as follows.

(a) Microscopic simulation — the movement of each vehicle is traced through the study network. Detailed simulation of vehicle/road interaction is possible, but at the expense of computational resources. NETSIM and TRAFFICQ belong to this category.

(b) Macroscopic simulation — vehicles are no longer simulated individually. Vehicle movements on each link are modelled as progressions of vehicle bunches or platoons. The dispersion of each platoon is also modelled. SATURN, TRANSIGN, and TRANSYT belong to this category.

(c) Analytical modelling — vehicles are assigned into a road network according to traffic conditions expressed in functions commonly called link delay or speed-flow functions. These functions predict the delay or speed on a link as a function of traffic flows for various user-specified parameters or conditions. These parameters may include the capacity or the road type of the link. CONTRAM, LATM, and MICRO-ASSIGNMENT belong to this category.

Packages that belong to category (c) are sometimes also addressed as simulation models. In this paper, the use of the term simulation is restricted to categories (a) and (b) only.

NETWORK REPRESENTATION

The network representation adopted in these computer models is the usual node-link method. A node represents an intersection and a link represents a one-way traffic movement between two nodes. Trip generation or attraction occurs at the entry/exit nodes or centroids. There are two exceptions:

(a) LATM — trips are generated from links and are routed to destination links; this is thought to be more capable of modelling a real-world situation and permits detailed modelling of turning movements.

(b) MICRO-ASSIGNMENT — a node is located at mid-block in a street network so as to allow a detailed modelling of intersection turning movements in this package. Two nodes are required at mid-block to represent a two-way street.

TIME-DEPENDENT MODELLING

Most of the packages in *Table I* can accept an O-D matrix expressed as a function of time. This is achieved by dividing a period into several intervals, usually of 15 min duration. The travel demand for each interval is assumed to be constant in that interval. The matrix is usually specified so as to model the growth and decay of a peak demand in the total modelling period. Queues that are not dissipated at the end of an interval are transferred to the succeeding interval. The exceptions are TRANSIGN and TRANSYT (all versions), which can only be used for single period modelling, although the TRANSYT model uses time-dependent queuing theory. TRANSIGN is implemented as a combination of TRAFFIC, an equilibrium assignment package by Nguyen and James (1975), and an earlier version of TRANSYT. Its facilities are therefore limited by what is available in the early version of TRANSYT.

EVALUATION

As already mentioned, the evaluation of the eight models is subjective. It is based on studies of the available literature on these packages and on private communication with some of the authors. Of the eight models, NETSIM and TRANSYT/8 have been implemented at the ARRB Cyber 171 computer, and TRANSIGN was tested as an ARRBTRAFIC-TRANSYT combination as reported in Luk (1978).

The evaluation criteria considered will include:

(a) the level of detail;

(b) possible applications and previous validations;

(c) the assignment algorithm adopted in the model;

(d) computational requirements; and

(e) documentation.

In *Tables II* to *VI*, the performance of each model in each evaluation criterion is represented by the number of stars that the model scores. A score of five stars denotes the best possible performance.

LEVEL OF DETAIL (TABLE II)

All assignment packages (1 to 5) are either analytical or macroscopic simulation models and do not provide as much detail as the microscopic NETSIM and TRAFFICQ models. These microscopic models can explicitly simulate the effect of pedestrians and several vehicle types including cars, buses and heavy vehicles. NETSIM can also simulate car-following, lane-switching, acceleration/deceleration and lane-blocking. TRANSIGN and MICRO-ASSIGMENT are less detailed in model structure than the others, and are currently capable of modelling one vehicle type. Other vehicle types in these models have to be expressed in terms of passenger-car equivalents. As previously mentioned, TRANSIGN and TRANSYT/8 cannot accept an O-D trip matrix that is expressed as a function of time, and are suitable only for single period modelling.

All packages except MICRO-ASSIGNMENT claim to be capable of modelling the effect of downstream blocking due to demand exceeding the capacity of a link during congested periods (see *Table II*). The microscopic models, NETSIM and TRAFFICQ, again provide a more detailed simulation of conditions at near-saturation and

TABLE II

LEVEL OF DETAIL

Package	Modelling Technique	Vehicle Types	Oversaturation Modelling	Post-processing	Rating
1. CONTRAM	- analytical - time-dependent - route choice optimisation	cars buses heavy vehicles	lane blocking will affect delay and assignment	- assigned flows - fuel consumption - network travel time and delay	***
2. LATM	- analytical - time-dependent	cars heavy vehicles	lane blocking will limit further access; excess vehicles will be re-routed or remain in queue and dissipate in the next interval	- assigned flows - network travel time - network plotting - fuel consumption - screenline analysis - pollution generation	***
3. MICRO-ASSIGNMENT	- analytical - time-dependent	cars	does not simulate over-saturation	- delay/stops - fuel consumption - network plotting	**
4. SATURN	- macroscopic with platoon dispersion - time-dependent	cars buses	use 'suppressed flow' to keep track of over-saturation	- fuel consumption - network plotting with assigned flows	****
5. TRANSIGN	- macroscopic with platoon dispersion	cars	does not simulate over-saturation	- platoon progression plottings in TRANSYT - assigned flows - network travel time	***
6. NETSIM	- microscopic - time-dependent	cars buses heavy vehicles (pedestrians)	detailed modelling of lane blocking possible	- fuel consumption and emission - graphic display possible	****
7. TRAFFICQ	- microscopic - time-dependent	cars buses heavy vehicles (pedestrians)	detailed modelling of lane blocking possible	- link travel time, queue length - pedestrians delay	****
8. TRANSYT/8	- macroscopic with platoon dispersion	cars buses (pedestrians)	user-specified queue length restraint on each link	- fuel consumption - platoon progression - link travel time, stops, delay - pedestrians delay	***

over-saturation than others. TRANSIGN as a combination of TRAFFIC and TRANSYT should be capable of utilising the facilities in the latest version of TRANSYT (the eighth version). In particular, a constraint on the queue length in TRANSYT/8 can prevent the blocking of the upstream intersection at a congested link. Since the publications related to TRANSIGN have been based on earlier versions of TRANSYT, it is therefore assumed that, in the evaluation of TRANSIGN, TRANSYT/8 is not used in combination with TRAFFIC.

Post-processing is available in all models to produce measures of effectiveness such as the network journey time/delay, stops and speed. Fuel consumption is modelled in all models except TRANSIGN and TRAFFICQ. Pollutant emission is available from LATM and NETSIM as well. Network plotting with assigned flows for each link is available in LATM, MICRO-ASSIGNMENT and SATURN. All packages appear to be capable of modelling the impact of implementing a variety of control measures including priority junctions, turn bans, signals, roundabouts, etc. Of the eight models, NETSIM, TRAFFICQ and TRANSYT/8 are more suitable for detailed investigation of signal control. In particular, TRANSYT/8 is a well-proven, and widely-accepted, package for co-ordinating traffic signals. NETSIM is the other model that has also been circulated and tested in several countries. Both NETSIM and TRAFFICQ are capable of simulating the operation of a VA traffic controller, although the simulation may be limited to particular types of VA operation. All the other models are only useful for fixed-time control operations.

APPLICATIONS AND VALIDATIONS (TABLE III)

Most packages were found to be validated only on limited real-world networks. They have yet to be accepted as a general traffic planning and design tool. Of the five assignment models, CONTRAM appears to be useful for most major applications such as signals, roundabouts and priority junctions. It can also be used for route choice and signal timing optimisation. TRANSIGN is also capable of route choice and signal optimisation. It was, however, found that the combined problem of assignment and signal optimisation is a non-convex problem and that the model does not guarantee a global solution (Charlesworth 1977; Luk 1978). The solution, i.e. a flow pattern that is mutually consistent with a set of signal timings, is found to be dependent on the initial flow pattern (or signal timings). This problem can be avoided if the signal settings are kept constant in the assignment algorithms, as in LATM, SATURN and MICRO-ASSIGNMENT.

Signal co-ordination can be investigated in all models except LATM and MICRO-ASSIGNMENT. Apart from TRANSYT/8 (and hence TRANSIGN), CONTRAM is the only other model that has the capability of optimising signal settings for minimum delay or other objective functions. TRANSYT has been used and validated world-wide. It therefore receives three stars in *Table III.*

ASSIGNMENT ALGORITHM (TABLE IV)

All five assignment models adopt techniques that can be broadly designated as iterative, multi-path, capacity

TABLE III

APPLICATIONS AND VALIDATIONS

Package	Applications	Special Features	Validation	Rating
1. CONTRAM	- signals (fixed-time), roundabouts, priority junctions - route choice and signal optimisation	route diversion strategies can be simulated by changing the capacity of certain links and passing 'messages' to vehicle packets	UK - Reading	***
2. LATM	- signals (fixed-time), roundabouts, priority junctions - route choice optimisation	freeway merging and diverging; interaction between freeway and local area; links with large-scale network assignment model and arterial road simulation model	Australia - Hawthorn - Waverley - Bayswater	**
3. MICRO-ASSIGNMENT	- signals (fixed-time), priority junctions - route choice optimisation		USA - San Jose	*
4. SATURN	- signals (fixed-time), roundabouts, priority junctions - route choice optimisation	generation or supplementing O-D trip matrix from traffic counts	UK - Harrogate - Liverpool - Wakefield	****
5. TRANSIGN	- signals (fixed-time) - route choice and signal optimisation		UK - Glasgow	**
6. NETSIM	- signals (fixed-time and v.a.) - priority junctions	lane-switching, car-following and acceleration/deceleration modelled	USA - Washington,DC - Utah - New Jersey	**
7. TRAFFICQ	- signals (fixed-time and v.a.) - roundabouts - priority junctions		UK - York - Wandsworth	***
8. TRANSYT/8	- signals (fixed-time) - priority junctions - signal optimisation		widely tested and used all over the world	***

TABLE IV

ASSIGNMENT ALGORITHM

Package	Method	Rating
1. CONTRAM	Deterministic, multi-path capacity restraint; convergence observed	***
2. LATM	Probabilistic, multi-path, capacity restraint; convergence observed	***
3. MICRO-ASSIGNMENT	Deterministic, multi-path capacity restraint; convergence observed	***
4. SATURN	Equilibrium assignment with convergence and optimality guaranteed	****
5. TRANSIGN	As in SATURN	****
6. NETSIM	No assignment	
7. TRAFFICQ	No assignment	
8. TRANSYT/8	No assignment	

restraint methods. SATURN and TRANSIGN are identical in that both adopt the equilibrium method. By optimally combining a sequence of all-or-nothing assignments, this method produces a user-optimised or system-optimised flow pattern (Wardrop 1952; Luk 1978; Akcelik 1979). For a given O-D trip matrix, convergence is guaranteed as long as the speed-flow relationship is monotonically decreasing, i.e. speed decreases as flow increases.

The equilibrium technique is theoretically superior to techniques adopted in the other assignment models. It is given one more star in *Table IV*. However, the equilibrium technique assumes certain route choice restrictions such as perfect network knowledge and identical perceptions of network conditions by all travellers. Furthermore, Wardrop's equilibrium principle applies only for entire trips, not segments within a trip. Different parts of a journey may involve different route choice behaviour. For example, a forced change of route at the start of a work journey may be resisted more strongly than one 'en-route', perhaps because it is closer to the point of origin and there are fewer alternatives leading to it in the choice set. Hence, route choice at equilibrium is a complex issue and other asssignment techniques may be equally appropriate in particular studies. The assignment methods adopted in CONTRAM, LATM and MICRO-ASSIGNMENT are different from one another, but all claim to be capable of convergence in five to ten iterations in most applications. Packages 6 to 8 are not given any score because they do not have assignment capability.

COMPUTATIONAL REQUIREMENT (TABLE V)

The memory requirement for implementing computer models depend on the size of the network to be modelled, i.e. the number of nodes and links. It will also be dependent on the program size, which in turn depends largely on whether the model is microscopic, macroscopic, or analytical. A microscopic model tends to require substantially more memory to keep track of the status of each vehicle, such as speed and position.

The status of a vehicle in a microscopic model can be updated on a time-scanning basis at regular intervals of, say, one second. It can also be updated on an event-scanning basis, i.e. until a event such as the generation of a vehicle takes place. A time-scanning microscopic simulation model usually requires more computational time but is simpler in model structure and programming. NETSIM and TRAFFICQ are time-scanning models.

The high-level language FORTRAN IV is used in all models except MICRO-ASSIGNMENT. The main program of MICRO-ASSIGNMENT, called MICRO, was written in the IBM/370 assembly language, and other subroutines in FORTRAN IV. This model is therefore far less portable than all other models and receives one star in *Table V*. TRAFFICQ was originally developed in CSL (Control and Simulation Language), and is now available also in FORTRAN IV.

In recent years, there has been a trend towards the use of high-level languages in microprocessor-based systems. This trend has created the need for more memory space, greater execution speed and easier access to software library. An 8-bit microprocessor such as the Z8108 can now address up to 512K bytes (1 byte = 8 bits) of physical meomory space with a speed range of 6 to 25 MHz (Whitcomb 1982). As the compiler for Fortran is usually available for these systems, most of the packages described in this paper can be implemented on microprocessor systems. The package TRAFFICQ is now available under the CP/M (Control Program for Microcomputer) operating system. The adoption of a common microprocesssor operating system such as the CP/M by most manufacturers has further enhanced the portability of microprocessor software.

DOCUMENTATION (TABLE VI)

NETSIM, TRAFFICQ and TRANSYT/8 appear to be better documented than the others. TRANSYT, in particular, has undergone many revisions and the user's manual is now clear and very few errors should remain. NETSIM is well-documented but was found to be difficult in creating the input data base.

TABLE V

COMPUTATIONAL REQUIREMENT

Package	Programming Language	Memory Requirement	Central Processing Time	Rating
1. CONTRAM	FORTRAN IV	Information not available from published literature	Low	***
2. LATM	FORTRAN IV	46K words for 200 nodes on Cyber 76	Low	***
3. MICRO-ASSIGNMENT	IBM 370 Assembler & FORTRAN IV	53K words for 170 nodes on IBM 370	Low	*
4. SATURN	FORTRAN IV	200 words per node plus basic program size on Amdahl 1	Medium	***
5. TRANSIGN	FORTRAN IV	About the same as TRANSYT	Medium	**
6. NETSIM	FORTRAN IV	45K words† for 20 nodes 600 vehicles on Cyber 171	High	**
7. TRAFFICQ	FORTRAN IV or CSL (Control & Simulation Language)	55K words for 60 nodes; also available on CP/M system	High	***
8. TRANSYT/8	FORTRAN IV	45K words† for 50 nodes on Cyber 171	Low (if no optimi-sation	***

† memory requirement minimised by overlaying or segment-loading.

TABLE VI

DOCUMENTATION

Package	Published Materials	User's Guide	Rating
1. CONTRAM	Few	Reasonable	**
2. LATM	Sufficient and clear	Reasonable	***
3. MICRO-ASSIGNMENT	Few	Reasonable	**
4. SATURN	Sufficient and clear	Reasonable	***
5. TRANSIGN	Sufficient	Not published	**
6. NETSIM	Many and clear	Clear and detailed	*****
7. TRAFFICQ	Sufficient	Clear and easy to use	****
8. TRANSYT/8	Many and clear	Clear and easy to use	*****

SATURN, MICRO-ASSIGNMENT, LATM and CONTRAM are also reasonably documented. The user's guide for TRANSIGN has not been quoted in the published literature in *Table I*, but presumably would be available on request.

DISCUSSION

The usefulness of a package depends very much on the type of network and the problem under consideration. For example, LATM is particularly suitable for studying route diversion in a local residential area with few or no signalised intersections, whereas TRANSYT is ideal for studying signal co-ordination in the CBD of a city. The user has to make the final choice according to the needs of his study. He should be aware of the limitations of the model of his choice, and the methodologies adopted in its development. This will allow him to comprehend and interpret the model outputs, which are usually difficult to understand.

The results of the appraisal are summarised in *Table VII.* SATURN appears to be an 'all rounder'. It has a theoretically sound assignment technique and a sufficiently accurate simulation of traffic progression through a network. It is also capable of modelling a variety of control measures for both cars and buses. However, the Australian traffic operations may be different from those in use in U.K. as modelled in SATURN. For example, the gap acceptance behaviour at a roundabout in Australia may be quite different from that in some overseas countries. There may therefore be some advantage in applying LATM for local networks. Further, LATM is currently under extensive development. The future enhanced LATM model may prove to be a very useful tool for small area traffic management studies.

This paper considers the eight traffic management models at the level of small networks. These models are also capable of predicting the impact of a management measure at the level of a road segment within the network. In particular, the microsopic models simulate and track the movement of a specific vehicle throughout its journey within a study area. In their current forms, none of the eight models can be used to address the broader, but closely related issues of land-use, distribution and mode choice. A previous study that linked the assignment model ARRBTRAFIC with the land-use/distribution model TRANSTEP was reported by Luk and Nairn (1980). The study utilised the Newcastle (N.S.W.) network and adopted an iterative sequential procedure to obtain an equilibrium between the demand for travel and level of service provided by a network. An equilibrium solution was located after four to five iterations, but further iterations led to oscillations with an amplitude of 5 to 10 per cent around the theoretical equilibrium point. This order of accuracy or resolution is sufficient for long-term strategic planning, but may be of limited use for small area management. Further research may provide techniques that reduce the oscillation and accurately isolate the equilibrium point. However, the possibility of an equilibrium between land-use planning, which has a long-term effect, and a short-term event such as traffic re-routeing may have to be established first.

CONCLUSIONS

The study of the eight models selected for appraisal indicates that there is as yet no single package that can model all of the control measures commonly adopted for traffic management. There appears to be a gap between the macroscopic assignment models such as CONTRAM, LATM or SATURN and the microscopic simulation models such as NETSIM or TRAFFICQ. The assignment models can study the re-routeing effect of control measures but do not have the details to simulate driving behaviour such as lane-changing, lane-blocking or acceleration/deceleration. On the other hand, a simulation model without the capability of assignment is limited in its use as a traffic planning tool. Hence, the user should be cautious about the choice of a model to meet the needs of his study. Apart from TRANSYT, the experience of applying these models to real-world networks is also largely limited to those who originally developed the models. There is a need to develop the experience and expertise by using some of these models in case studies under Australian traffic conditions. A comparative study of these models should review areas for further refinement, and situations which are best analysed by a specific model.

TABLE VII

EVALUATION RESULTS

Package	Level of Detail	Application and Validation	Assignment Algorithm	Computational Requirement	Documentation
1. CONTRAM	***	***	***	***	**
2. LATM	***	**	***	***	***
3. MICRO-ASSIGNMENT	**	*	***	*	**
4. SATURN	****	****	****	***	***
5. TRANSIGN	***	**	****	**	**
6. NETSIM	****	**	†	**	*****
7. TRAFFICQ	****	***	†	***	****
8. TRANSYT/8	***	***	†	***	*****

† not available.

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