AN AUSTRALIAN EVALUATION OF SATURN

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ABSTRACT: *The suite is interesting in its sophistication and can allow the evaluation of systems normally beyond any manual re-assignment of traffic. However, its very sophistication leads to problems of interpretation, validation and calibration. The interaction of the various parts of the suite was studied in order to assess the relative contribution to the modelling process.*

This paper describes the processes of the suite together with its validation and calibration for Australian conditions. The area chosen for the test was a suburban, regional shopping centre in Sydney.

So far the results obtained from using SATURN have been encouraging. The models performed in a reasonably coherent and understandable manner and enabled the evaluation of a number of difficult problems in a much quicker and more detailed manner than is normally possible.

The ideas and opinions expressed in this paper are those of the authors and are not necessarily those of the Department of Main Roads.

Background.

The Department of Main Roads, New South Wales, is responsible for classified roads within New South Wales, the responsibility being shared by fourteen Divisional Offices throughout the State. Metropolitan Division is situated in the most densely populated area of Sydney and therefore has special traffic problems related to the high traffic generation. Traffic volumes and congestion have reached a level where the capacity of the arterial roads has been exceeded and overflow traffic to residential streets has become a great concern to residents and local councils. Councils in turn, have acted to remove the traffic by traffic management measures usually involving road closures. In the past, the Department had no way of objectively analysing the effects that these proposals had on the arterial road system other than to guess or carry out a manual redistribution of traffic. Thus, a small area traffic model was seen as imperative for the following reasons:

1. The effect of Council proposals on the arterials could be gauged.

2. Objective comparisons of different traffic management schemes could be made quickly, easily and, above all consistently, and

3. Solutions arising from the modelling would be more favourably received by Council.

The search for a model led to four possibilities:

SATURN, from University of Leeds, U.K.
LATM from CSIRO
CONTRAM from TRRL, U.K.
NETSIM from Federal Highway Administration, U.S.A.

The limited capacity of NETSIM made it unsuitable for the Department's purposes.

Approaches were made to obtain the other three, but CONTRAM was then not available to the public. Both SATURN and LATM were obtained. However, this paper relates to work with the SATURN model. (Work is progressing on the evaluation of LATM and it is hoped that a report will be published in the near future).

SATURN was seen to have two valuable advantages over the other models; it had the facility to create a trip matrix from traffic counts, (counts being the easiest and most economical data to collect by the Division, trip tables the hardest data to obtain) and a buffer network facility which would better enable the effect on the surrounding arterials to be gauged.

The SATURN Model

A detailed explanation of the model is given in Ferriera, Hall and Van Vliet (1980) and interested readers should refer to this publication. However, some theoretical aspects of the models are presented here for completeness.

SATURN is an extremely complex suite of programs which can be viewed as containing three main models. These are the simulation model (SATSIM), the assignment model (SATASS), and the matrix build model Maximum Entropy Matrix Estimation (ME2).

Although sophisticated, the SATURN suite is somewhat similar to two or three other suites currently available. However, SATURN has one unique feature which is not currently available in any other models. It has the ability, using an entropy maximisation technique, to create matrices from counts. Basically, the model compares and creates a series of trip matrices by analysing the number of trees through links which contain counts. This is done by defining a variable for the probability that the trip from the origin i to destination j takes the link A (Pija). The Pija factors are then used to adjust the individual matrix elements (ij pairs).

Naturally, this technique is not as accurate as collecting OD information, either from number plates or roadside interviews, however, counts are considerably cheaper. Indeed, where the Department is concerned counts can be obtained for a negligible cost from its SCATS system wherever signals exist. Thus, a cheap and up-to-date data bank exists for the potential off-line assessment of traffic management proposals.

THE STUDY

Chatswood was the logical choice for the initial study because of the interest in the Centre by both the Government and private developers. The Department of Main Roads' interest was to gauge the effect that the growth would have on arterial roads. However, the modelling work was eventually confined to the Town Centre and therefore its effects on arterials still had to be estimated. It is hoped to remodel the area using the buffer network facility to gain a better estimate of through trip diversion to the arterials.

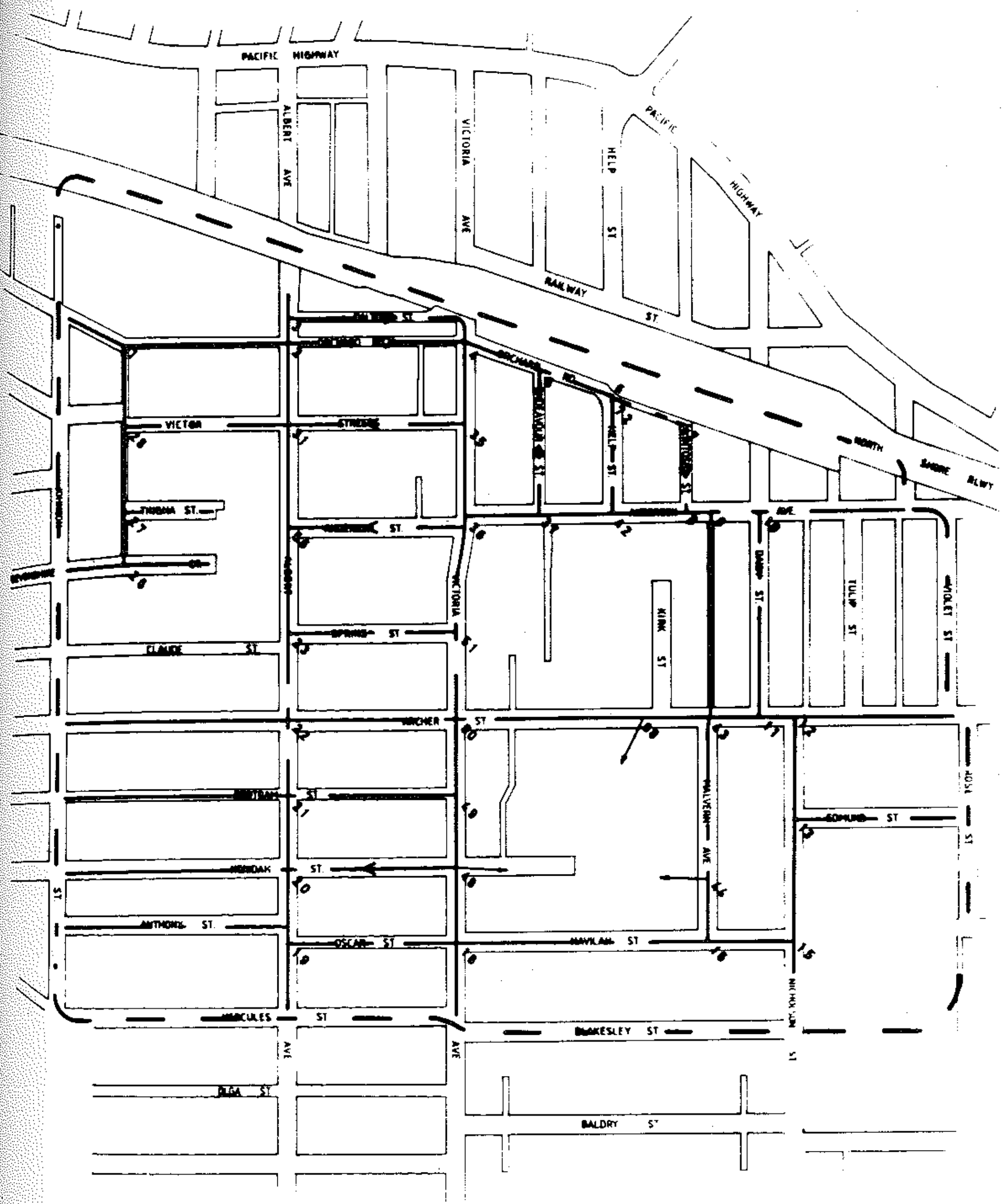


Figure 1 — The Chatswood Street System

The network as shown in Figure 1 was about 1 km square and consisted of 260 links, 540 simulated turns and 37 zones.

Compare this with the Sydney network which is about 50 km square and consists of 10,000 links, 4,500 nodes and 658 zones. The small size of the network was due mainly to the area of available data being confined to the immediate centre. This area had been the subject of numerous studies since 1971 including a comprehensive volume and parking survey in 1981 and a number plate survey in 1978. This meant that a reasonable data base could be completed by carrying out a small number of traffic counts.

The modelling work was carried out for a government appointed sub-committee to study Chatswood Town Centre. The brief was to examine the local and regional implications of firstly, a number of changes to the street system, and secondly, increased office and retail development arising from changes to floor space ratios.

SATURN was used to evaluate traffic effects of the changed street system combined with committed retail development over and above that existing in 1981. A total of 15 different street and development options were evaluated. The scope of this paper is mainly confined to the base year network and reports SATURN sensitivity to a number of traffic management devices evaluated at various times throughout the Study.

USING THE MODEL

Documentation

The SATURN users manual has changed significantly since the first document was received from Leeds in July, 1981. Many of the problems and ambiguities have been eliminated but the authors would anticipate new users having problems with terminology and application.

Some areas of documentation which need reviewing are:

1. Terminology - links, turns and roads.
2. Coding bus-only links. A change in program is also required for turns out of bus lanes.
3. Centroid connectors to external nodes and parking zones.
4. Setting out of the SATURN documentation, e.g. the parameters might be in alphabetical order for ease of reference.

The program documentation is just the reverse of the user documentation. The programs are well written and include copious comments. The program support documentation is also helpful and provides a useful intermediate step between the user manual and the programs.

Compilation

The programs are written in FORTRAN extended compatible with the AMDAHL computer at the University of Leeds. The only problem with compilation on the Department's Cyber 170 series computer was that some variables were defined as integers and real numbers in different parts of the program. This was simply overcome by placing quotation marks in the data statements as a temporary measure. In the latest version the data statements have been altered to make them more machine independent and all compilation problems have been eliminated, at least for the Cyber.

Network Coding

A clockwise convention for coding intersections must be strictly adhered to, otherwise potentially serious errors will arise in the simulation phase. Standard conventions for coding node order are used (ascending) but one advantage is that zone and node numbers need not be sequential. This allows numbering systems from other studies to be used.

Some unconvential aspects of the coding are worth mentioning here.

Links

SATURN requires data for each turning movement at an intersection. This is done by coding for each approach the saturation flow and number of lanes for all turning movements possible. In addition, there must be a record to identify the type and location of the intersection. This means that for a four way intersection, there would be five records to code in SATURN compared to four for convential packages.

Centroid Connectors

There are two types of centroid connectors: two-way for external zones and one-way for parking zones. The connectors are, in fact, imaginary because they are related to links, not nodes. In the case of parking zones (one-way connectors) the links are nominated in a specific direction, upstream node first followed by downstream node. Up to six connectors are allowed for each zone (and therefore a limit of six one-way links per parking zone).

Zones

There are two types, external and parking. External zones represent points of trip generation either on a cordon or within the study area. Parking zones are used to simulate on-street parking, but may also be used for off-street parking areas in certain circumstances. Both types of zones are linked to the network via (unseen) connectors as previously explained.

Computing

As described previously the SATURN process consists of simulation and assignment stages carried out independently in internal iterative loops. These two stages are then combined in an iterative loop which should also converge. This process is illustrated by the flow chart in Figure 2. A larger outer loop incorporating simulation/assignment and the ME2 model is used in the matrix update stage and is illustrated in Figure 3.

The inner loop involving simulation and assignment only is controlled by standard 'procedures', which the SATURN authors wish to see used universally. The outer loop involving matrix updating requires intervention by the analyst. The danger of including the matrix building (updating) in an automatic procedure lies in the difficulty of tracing errors or particular movements when the individual matrix elements are changing with each iteration.

The method employed in the Chatswood Study consisted of two parts, matrix creation and simulation/assignment.

a. The process of generating a new trip matrix in SATURN was oriented towards updating an existing matrix. A matrix file was therefore required before processing in SATURN could begin. Two methods were used to derive the starting matrix:

   1. A unity matrix was fed into the Fratar process using volume counts for row and column totals (trip ends).

   2. A unity matrix was biased according to trip sub-totals based on the results of a number plate survey: through trips 40%, external-internal 30%, internal-external 20% and internal-internal 10%.

   A ME2 run was then performed using one of these matrices and the Pija factors.

b. Simulation/assignment loops were then performed holding the matrix fixed. This simplified the evaluation by reducing the number of variables to a manageable level. The network was validated using this method and a final matrix update and assignment were then carried out using the outer loop. Note that very little calibration is required unless for some reason the network links have very different saturation flows.

   CBD saturation flows from the NAASRA publication 'Interim Guide for the Design of Intersections at Grade' were used almost exclusively in the Chatswood Study. Only at two locations were they found not to apply and this was due to unusual characteristics of each intersection.

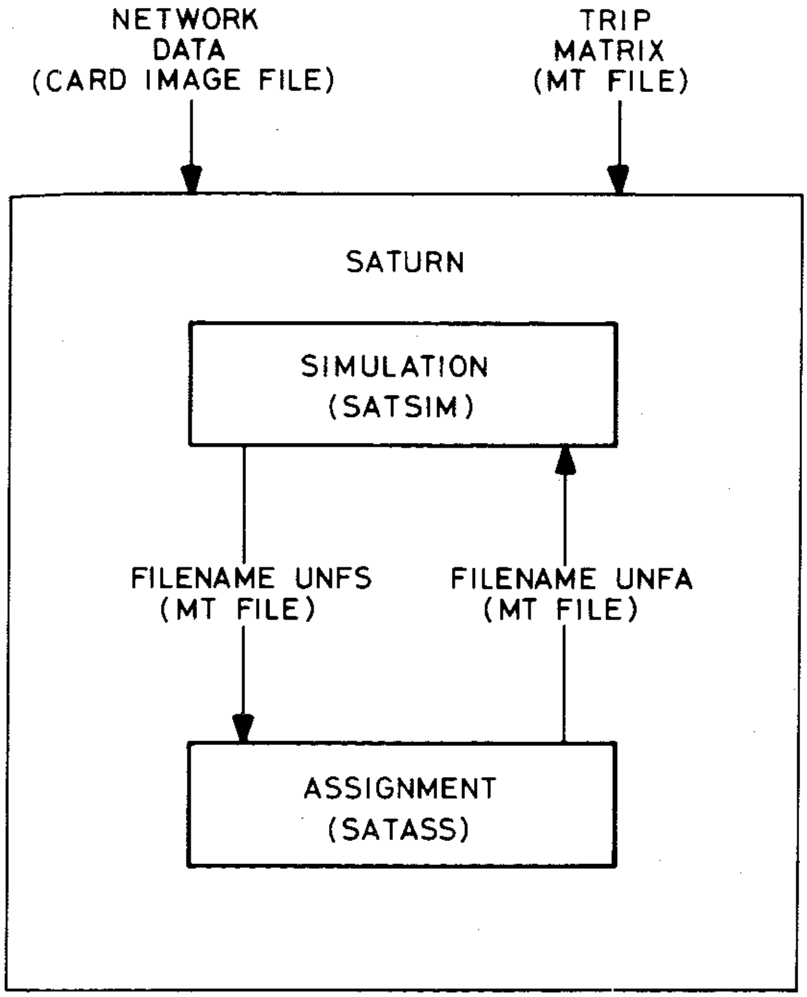


Figure 2 - Running the Basic Saturn Model

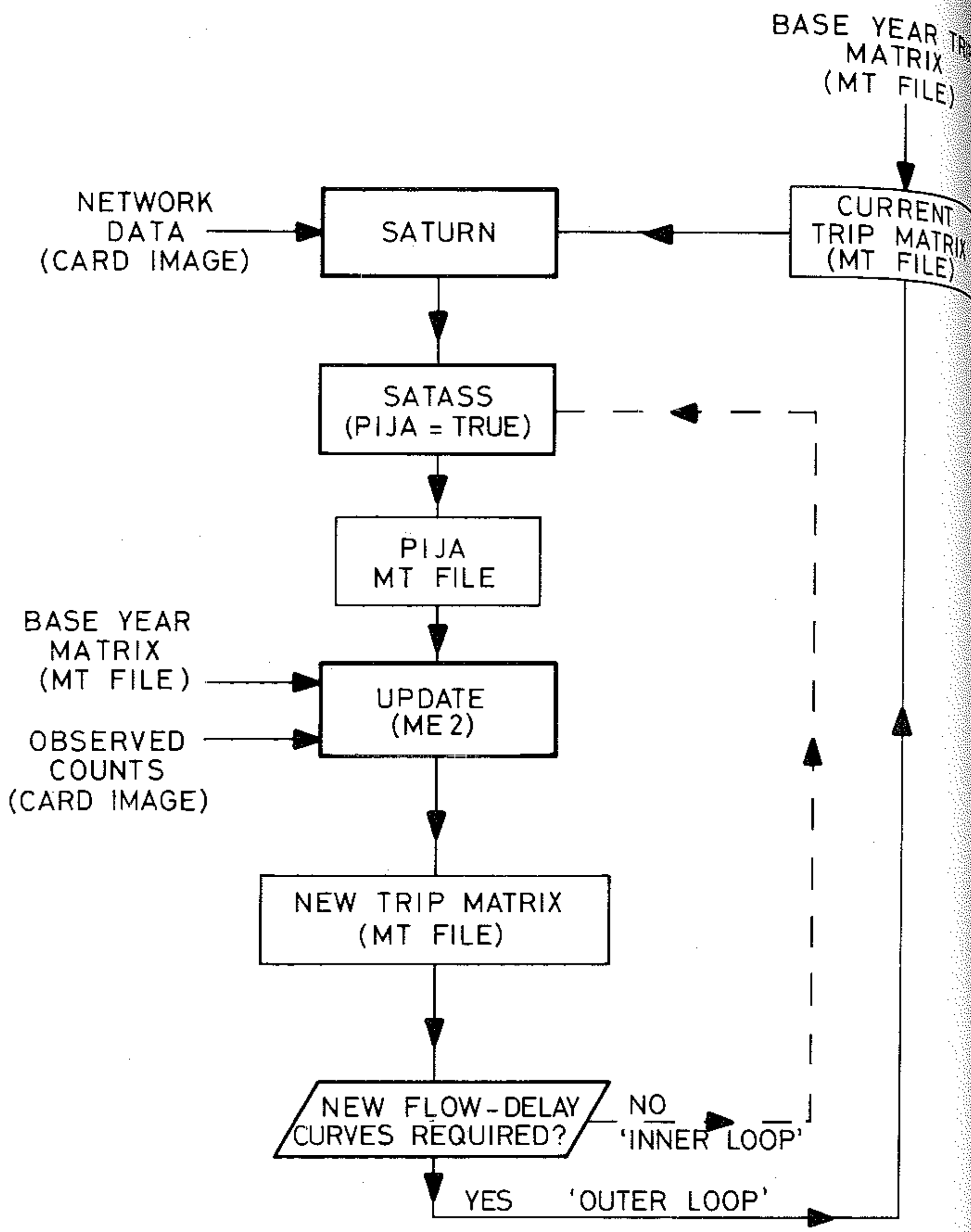


Figure 3 - Estimating a Trip Matrix

A Note on Processing Time

It should be borne in mind that SATURN requires much greater core than conventional assignment packages for a network of similar size. For example, a network the size of Chatswood, 260 links, 104 intersections and 37 nodes demanded an initial core request for SATSIM of 220,000 octal words. The TRANPLAN suite requires a similar amount for a complete Sydney network of 10,000 links for a stochastic (Dial) load. A typical simulation/assignment loop of 5 iterations took about 300 CP seconds and cost between $40 and $60 based on the Department's composite unit computer cost.

ASSIGNMENT RESULTS

Matrix Estimation

The first method using the Fratar model on trip end counts produced a subjectively satisfactory trip distribution, but it was found that the proportion of through trips at each cordon station was about 70% as shown in Table 1. The actual values as given by a number plate survey (1978) were found to be much lower (see Column 6 of Table 1). It was also found that any bias introduced in the starting matrix was effectively destroyed by the Fratar process, which if given enough iterations always converged on the proportions set by the trip ends. Additionally the Fratar model equitably distributed trips to all possible O-D pairs, no matter how unlikely the trip.

The second process using a biased matrix resulted in the through trip totals for each cordon crossing point as shown in column 10 of Table 1. The agreement appears poor but it was found that in general, the important O-D pairs (as indicated in the number plate survey) were given a compatible status in the modelled matrix, even though the totals were much larger in the latter. For example at cordon crossing station 6, the O-D pair 6-14 was 57% of total through traffic in the bias:ME2 matrix, 53% in the number plate survey, and 40% in the Fratar model.

It was noticeable from the magnitude of the volumes, that either the survey was in error or the distribution of trips to the Centre had changed dramatically between 1978 and 1981 or both. The difference in total trips crossing the cordon between the 1981 counts and the 1978 survey was over 900 or about 15% of the total trip matrix. The sheer scale of this difference coupled with the fact that number plate surveys generally underestimate through trips, tipped the balance in favour of accepting the matrix created by the second method.

TABLE 1

COMPARISON OF TRIP MATRICES

PERCENTAGE OF THROUGH TRIPS AT CORDON STATIONS

Cordon Station Zone	Flow In			Through Trips				
	No. Plate Survey	Fratar: ME2	Bias: ME2	No. Plate Survey		Fratar: ME2		Bias: ME2
				Vehs.	% of Total	Vehs.	% of Total	Vehs.
1	288	343	337	124	43	222	63	263
2	331	472	540	117	35	335	71	217
3	755	626	656	333	45	419	67	387
5	142	271	278	49	35	205	76	173
6	265	508	516	127	46	432	85	420
7	3	21	20	1	33	18	86	19
8	97	58	64	53	55	49	84	58
9	546	787	797	249	45	553	70	423
10	257	339	339	120	47	237	70	219
12	17	103	20	7	41	71	69	12
13	45	98	19	13	29	66	67	13
14	598	708	702	338	57	529	75	577
15	169	255	126	75	44	174	68	30
TOTALS:	3513	4589	4414	1606		3310		2811

Link volumes for the validated network.

Tables 2 and 3 present the assignment results for the validation (base year) network.

TABLE 2

LINK VOLUME STATISTICS

	Selected Links Counted Volumes		Assigned Volumes
Average vol.	289		301
Std. deviation	248		254
Variance	60,424		63,175
Absolute diff.		42.5	
Abs. diff. as %		14.4	
Range of diffs.	-133	to	107

t test: $t = 0.2675$ ∴ assume samples are the same at the 0.001 significance level.

f test: ratio of variances = 1.045 same conclusion as t test

Correlation between the two samples (counts and assigned volumes) count = 0.95383 * assigned volume + 1.5461 correlation coefficient = 0.98.

TABLE 3

ASSIGNMENT ACCURACY

x	% of links within x % of count	% of links within x % of count or 50
10	37	59
20	56	73
30	68	86

The goal was for assignment volumes to be within 10% (or 50 vehicles for links with volumes less than 200 vehicles per hour). As Table 3 shows, only 37% of the selected links were within the 10% limit and 59% the stated goal. In this regard the model did not perform as well as the Wakefield model as reported in Ferriera,(1981) and probably reflects the inaccuracies of the trip matrix and the complexity of the Chatswood network. However, the results are compatible with those obtained for Harrogate and Liverpool.

It should also be noted that although the overall results compare favourably with the British results, we were not nearly so successful at predicting precise volumes, as only 24% of links fell within 5% of actual volumes compared to the Wakefield study where 59% of links were within 5%.

Turning Volumes

TABLE 4

TURNING VOLUME STATISTICS

	Totals	Mean	Std. dev.	Variance
1981 counts	15,994	176	150	22,343
Assign vols.	16,857	185	164	26,668
Abs diff.	5,366	59	46	2,082
% diff.	5,209	57	64	4,056

Generally turning volumes were less successfully modelled than link volumes. The absolute difference was greater than for links although the mean was only about half that for link volumes. From the turning volumes the differences in routes (between model and reality) were observed. An indication of shortfalls in circulating traffic was also obtained from the turning volumes, e.g. on the streets surrounding the Lemon Grove Centre where turning volumes and the flow on Endeavour Street indicated a circulating volume of approximately 100 vehicles per hour, the model predicted a circulating flow of zero. At most of the major intersections in the network, the turning volumes were in aproximately the correct proportions.

Screenline volumes

Assignment volumes across screenlines varied from the counted volumes by between -4% and 11%. A screenline circumscribing the network gave indications of variation from actual volumes for the quadrants. The north east quadrant displayed a 15% difference to outbound counts and the south-west quadrant a 4% decrease over counts.

Prediction of queues

Queuing on the 1981 street system was observed at six locations. Only at one location did the queue extend over the hourly period. At two other intersections extensive queuing usually occurred between 4.00 and 5.00 p.m., but rarely extended beyond 5.00 p.m. being the result of local peaks in the traffic occurring over a short time. To successfully model this behaviour 15 or even 5 minute periods should be used. It was interesting to see that when the increased generation from the new development was added to the trip matrix, residual queues were predicted at both these intersections.

The model predicted that queuing would occur at three intersections, one being the intersection with the residual queue. The size of the queue (nine vehicles) was also in close agreement with observed queue length. However, it also predicted queues at two other locations of three vehicles and five vehicles. These queues reflected a larger than actual generation of on-street commuter parking. In reality only instantaneous queuing occurred at these locations.

Route Choice.

Two problems were evident from the assignments:

1. SATURN identified an attractive by-pass route which was either unknown to drivers or perceived not to be a reasonable alternative, and

2. Circulating traffic volumes in one area of the centre were underestimated.

The first was overcome in the Chatswood Study by "cheating": a time penalty was placed on the by-pass route to simulate the lack of knowledge of the route. The problem of the by-pass route seems to be a function of the mix of priority and signalised intersections, and this hints that SATURN might be more successfully employed evaluating networks with a predominance of one type of control.

The difficulty in simulating circulating traffic stems from the trip table rather than the assignment, but is included in this section because it is characterised by a flow discrepancy, in this case a shortfall of 100 vehicles per hour. It is possible to simulate circulating volumes by weighting the matrix elements close to the diagonal in the area giving trouble. However, this involves returning to the original matrix and working through the process again. Time precluded this in the Chatswood Study so the error was tolerated.

SENSITIVITY OF THE MODEL TO VARIOUS TRAFFIC MANAGEMENT MEASURES

Changes in road geometry

In the course of the study, it was found that a queue of through vehicles developed along a major link behind right turners at a priority intersection because only one approach lane had been coded. This problem did not exist in the base network because the volumes were not large enough to cause problems. For the case of the greater development a queue of 22 vehicles was predicted for the blocked through movement. The intersection was recoded with one through lane and one right turn lane with the results shown in Table 5.

TABLE 5

SENSITIVITY TO CHANGES IN GEOMETRY

	No Turn Bay	Turn Bay
Base network		
volume on major appr.	395	396
queue on major appr.	Ø	Ø
volume on minor appr.	525	530
queue on minor appr.	Ø	Ø
total queue at int.	Ø	Ø
total queued on net.	18	17
New development network		
volume on major appr.	462	598
queue on major appr.	22	Ø
volume on minor appr.	516	490
queue on minor appr.	4	20
total queued at int.	26	20
total queued on net.	180	134

<u>Change in intersection control.</u>

Figure 4 illustrates the changes to route choice caused by replacing a priority junction with traffic signal control.

It can be seen that the signals have a dramatic effect on volumes on the north-south leg of the intersection and on turning movements and route choice for the east-west traffic. The parallel route to the north of main street (72-8) acts as a "safety valve" for left turners 72-42-8 when the queue reaches the vicinity of 72. The introduction of signals caused most of the left turning traffic to turn right instead, presumably because this route had become more attractive. In turn this has pushed the captive left turning traffic onto the smaller by-pass.

<u>Functional change in street system.</u>

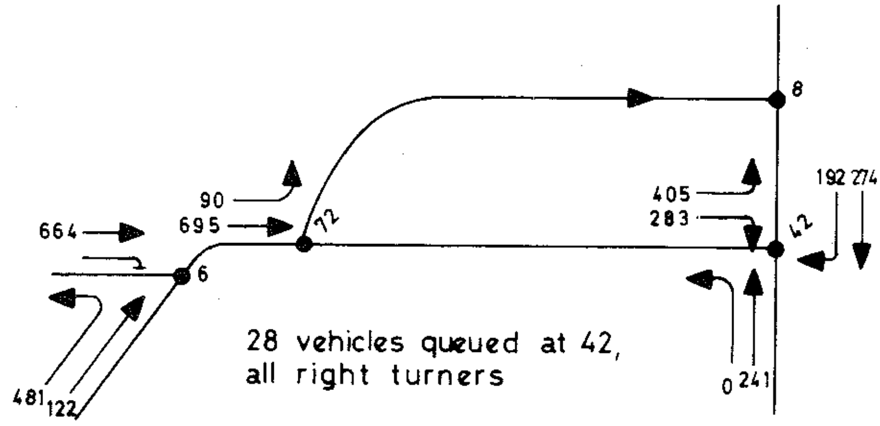
Functional changes to street systems usually involve more subtle changes to network parameters. One of the stumbling blocks to progress in the planning process for Chatswood Centre was the difficulty in achieving agreement on re-routing buses. The existing system had buses feeding the Centre directly. The new proposal was to close the existing feeder road, which would then become a pedestrian mall, and to re-route buses to a road 200 metres south of the Centre. This road would then feed buses into a bus/rail interchange. The proposal was not accepted, but a compromise was reached where Centre-bound buses would use the southern route and outbound buses the pedestian mall, which would become a partial mall.

To illustrate the types of differences in network effects that SATURN might reveal, an example showing comparisons between the compromise network (network 1) and a network with buses using the mall in both directions (network 2) and not the southern route is illustated in Table 6. Figure 5 shows the difference in turning volumes between the two networks.

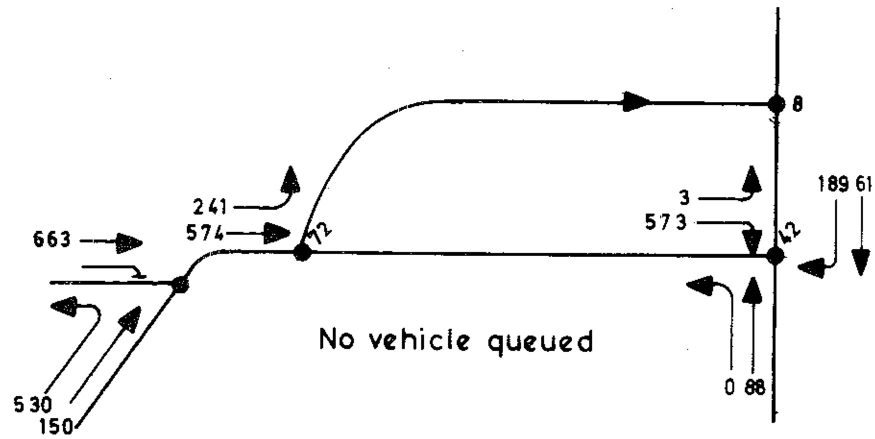
TABLE 6

NETWORK EFFECTS OF A CHANGE IN STREET FUNCTION

	Total Queued	Av. Trav. Time	Av. Trip Length	Fuel Consumption
Network 1	60	115secs	0.603	914
Network 2	38	109secs	0.606	889



a) PRIORITY INTERSECTION



b) 2 PHASE SIGNAL CONTROL

Figure 4 Change in intersection control

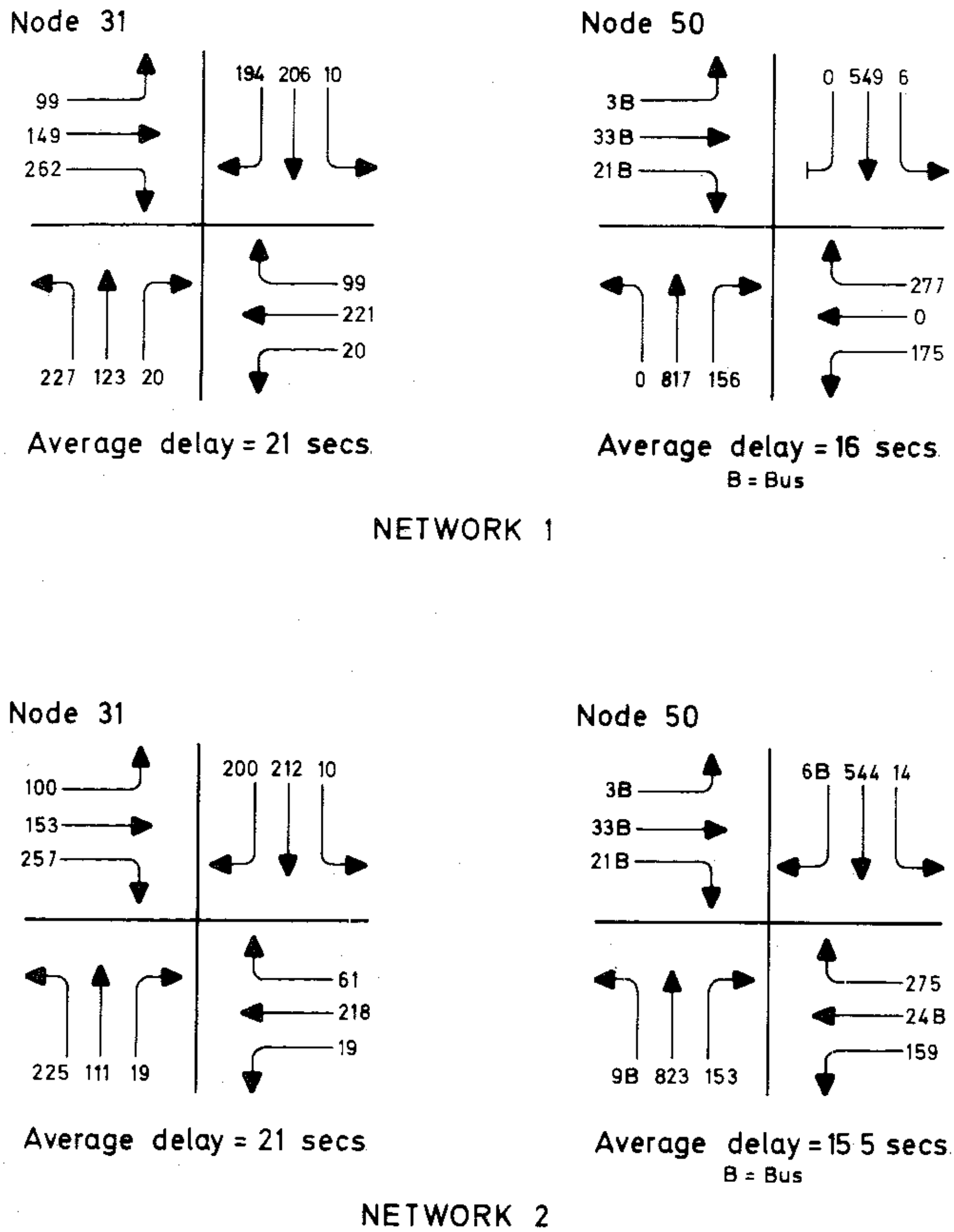


Figure 5 Sensitivity To A Functional Change In Street System

This functional change produced very little re-routing of private vehicles and almost insignificant change at the two major intersections involved. The overall network changes were however, more significant indicating that buses using the mall in both directions would be preferable to one direction only.

CONCLUSIONS

Was the theory comprehensible?

Although the theory behind each of the three main parts of the SATURN suite is understandable and thus, in isolation, the operation of each model can be predicted, in combination, their interaction makes prediction extremely difficult. It is hoped that greater use will lead to a better "feel" for the reaction of the suite to data and/or parameter changes.

Conversely it is the sophistication of SATURN and its major innovative advantages over its competitors, that make it unsuitable for general use. It is believed that a good understanding of the basic theory behind each step and the interaction between processes is necessary before users could be confident of the values of their results.

Were the results acceptable?

Judging purely on the assignment results and comparing with past experience with conventional packages, the authors would have no hesitation in accepting the results for Chatswood. However, the sophistication of the model and the purpose for which it was designed, leads the user to adopt a much more critical view.

Matrix Creation

The final validation matrix had some serious problems when compared with the number plate survey results. For areas such as Chatswood, having a complex traffic generation, a reliable first estimate matrix should be used as input to the ME2 model. The Fratar model was found unsuitable for this purpose. When using a unity matrix as the first estimate, the matrix elements must be biased to ensure that a reasonable trip distribution is produced. The ME2 model did preserve the structure of that matrix. Employing ME2 to create a satisfactory trip matrix from traffic counts only on simple networks is yet to be tested, but the results of this study are sufficiently encouraging to proceed in that direction.

Assignment Results

The link volumes were regarded as reasonable, particularly when comparing volumes arising from different traffic management strategies. Volumes for forecast years remained as unpredictable as conventional assignments, because the major uncertainties originated in the trip table which was derived using standard prediction techniques for generation by floor area and local council parking codes.

Turning volumes were less successfully predicted and the authors would prefer more experience with SATURN before these are used for traffic signal design.

Route Choice

The final "preferred" paths evident in the assignment (assessed on turning volumes only) were a function of the network (hence the assignment process) and the trip matrix. It was evident that there were some paths chosen by SATURN which were not used in reality. Two major differences were identified:

1. by-pass routes which were not known by drivers, and

2. the circulating traffic in certain areas of the centre.

Neither of these problems are new and in this regard SATURN performs as well (or badly) as other traffic assignment models. SATURN however, has the potential to simulate circulating traffic with a reasonable degree of accuracy through the matrix updating facility.

Are there any reservations as to the application of SATURN?

Although no technical reason has been found to limit the application of SATURN there are several practical limitations. These stem from the larger than usual data requirements of the suite. Thus, it is probable that although the external equibrium model in SATURN may be used to look at strategic alterations in flows due to central changes in road supply to trip demand, less "data-hungry" models such as CSIRO's LATM may be more appropriate for local residential areas etc. This is not to say that SATURN is unsuitable only that it may be more efficient to use other less demanding models.

Was it easy to use?

The short answer to this question is no.

Data requirements were not excessive, but it was concluded that for a centre as complex as Chatswood, reliable count and trip distribution information must be available. It is hoped that smaller, less complex networks will require only traffic counts, but this is still to be confirmed in a study. Coding was more complex than conventional assignments, but if the conventions were rigidly adhered to, little trouble resulted. Human error is more likely because of the complexity and the errors were not always uncovered by the editing routines.

The major difficulty in using the suite was in the interpretation of the SATURN manual. However, the program is still in its infancy of public use and will no doubt undergo change, which in turn should lead to evolution of the user manual. Whether the program will reach the stage of a "black box" is doubtful, mainly because of its sophistication, rather than any deficiencies that now exist in its documentation or theoretical basis.

Would we use it again?

The Department is currently undertaking a corridor study in Newcastle and there are also plans by the Australian Road Research Board to carry out a comprehensive assessment of SATURN on the Parramatta Centre area. At this stage, it is too early to predict whether SATURN would be used as a matter of course by the Department's Divisional Offices, but it will certainly be considered for any small area work in the Metropolitan Area of Sydney.

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