SATURN TRAFFIC MANAGEMENT MODEL EVALUATION

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ABSTRACT

The SATURN model was acquired to analyse traffic patterns in a congested Melbourne Suburb. The model is briefly described and a comparison of its capabilities and data requirements made with the UIPS package of programs. Experience gained with mounting and running the package is presented, including tests made on various program parameters and differing network configurations. These factors were found to influence predicted traffic volumes, and SATURN's applicability to studies of new routes is examined.

MODEL BASIS

SATURN (Simulation and Assignment of Traffic in Urban Road Networks) is a detailed model intended for use in the evaluation of traffic management schemes. Version 4.1 was obtained by the Road Construction Authority of Victoria in late 1984. Several man-months were spent installing, debugging, testing and operating the model. The model's background and basis has been described in a number of well-documented papers, but for this exercise, the user manuals accompanying the programs provided all of the information required to operate the model (Ferreira et al 1981).

SATURN is a sophisticated traffic assignment model with a detailed simulation of delays at intersections. It assumes that the traffic is represented by a fixed trip matrix and therefore it is most suitable for the analysis of "movement-based" control systems such as one-way streets, signalised intersections, and bus-only lanes, as distinct from measuring trip generation or mode choice effects. The two parts of the model include a detailed simulation of delays at intersections, coupled with an assignment phase which determines the routes taken by the vehicles (Van Vliet 1982).

The simulation aims to determine junction delays resulting from a given pattern of traffic. Two fundamental assumptions are made in this process. Firstly, traffic flows are constant over time periods of the order of 30 minutes. Secondly, for simulation purposes, a cyclical behaviour is imposed on the flows by traffic signals operating with a common cycle time. (Ferreira et al 1982).

Within each cycle, traffic is represented by semi-continuous "flow profiles". As traffic moves from one intersection to the next, its flow profile is modified according to platoon dispersion to yield the shape of the profile arriving at the next intersection. The shape of the profile which then leaves that intersection is determined essentially from the arrival profile and the maximum traffic flow that is free to make each turning movement at any moment during the cycle. The latter "accept" profile is a function both of the junction control strategy and of opposing flows if any. By these means the model accounts for delays caused by opposing flows, e.g. right-turning traffic, and delays due to vehicles on the same link, e.g. the effect on straight-ahead traffic of impeded right-turners in a shared lane. The model also accounts for the shape of arriving profiles, the effect of phase structure and offsets at traffic signals, as well as the allocation of turning movements to lanes. SATURN also models signalised, priority and roundabout intersections on a separate basis.

The assignment phase aims to select minimum time routes through the network for each element in the trip matrix, bearing in mind the simulated relationships between travel times and turning flows. The model uses an equilibrium technique based on an optimum combination of all-or-nothing assignments and multipath route choice. This type of assignment has previously been found to suit the Melbourne road network (Apelbaum and James 1983).

The complete model is based on an iterative loop between the assignment program SATASS and the simulation program SATSIM. Thus the simulation determines flow-delay curves based on a given set of turning movements and feeds them to the assignment. The assignment in turn uses these curves to determine route choice and hence updated turning movements. These iterations continue until the turning movements reach reasonably stable values.

Before running these programs, the traffic network is initially built with program SATNET, while trip data is manipulated by programs M1 to M6. Traffic volumes and system measures are output by program SATLOOK and the plot routine P1.

A procedure closely linked with SATURN is the ME2 Model (Maximum Entropy Matrix Estimation) for predicting a trip matrix from a given set of traffic counts and optionally a previous trip matrix. ME2 produces a trip matrix which, when assigned, reproduces the observed link counts as closely as is desired.

SATURN allows the user to input bus routes and their frequencies independent of the trip matrix. Buses are then allocated as fixed link flows. This enables the choice of routes for the remaining trips to be made more realistically, and also enables SATURN to output separate performance measures for buses and other trips. In addition "bus-only" links may be defined. These have the effect of preventing car trips from being assigned to them, but ensure that the delays to buses at the corresponding intersections, as well as the effect of buses on cars, are properly modelled.

Routines have been added to SATURN to estimate fuel consumption. The equations used are standard and take into account "free-flow" driving time and distance, time spent queuing at intersections, and the number of stops (including multiple stops as traffic moves forward in a queue). Appropriate parameters for the "average" British car are used in these equations.

MODEL MOUNTING

The SATURN user manual was used to help install SATURN. The manual was found to be reasonably comprehensive, although it lacks an index (Ferreira et al 1983). Also, the user manual provides no description of the output printouts, thus hampering result interpretation. A condensed version of the user manual with index was prepared for Authority use by the authors.

The test case for Liverpool supplied with the package was used as input for all of the programs, and gave the expected results. The test case includes several options and errors to check out the package. It has 22 internal nodes and 12 external nodes and a large number of one way streets.

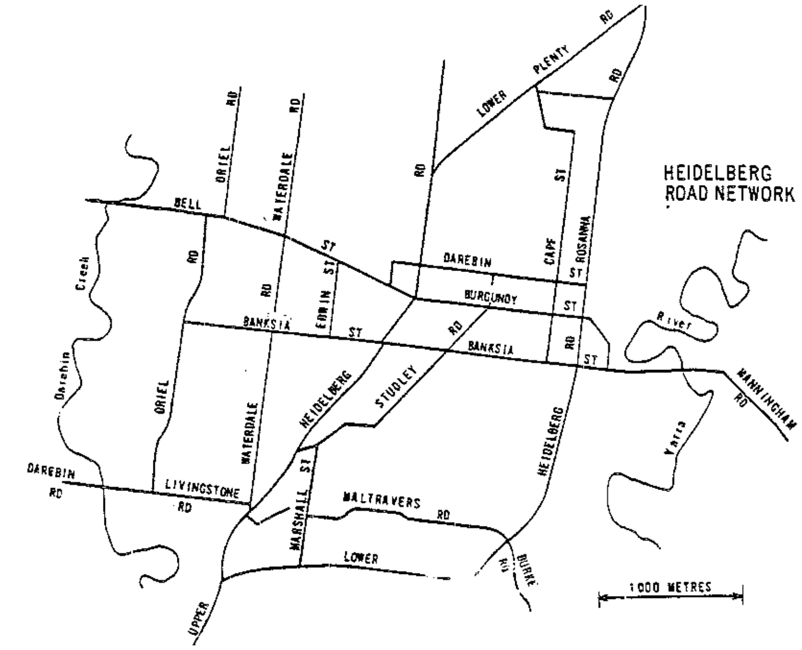
In mounting SATURN, a number of minor FORTRAN syntax changes were required. The manual outlined changes required to accommodate the model on a FORTRAN 77 system, as at the Authority. As well though, a couple of errors were found in the source code, and some missing arguments in calls to plotting subroutines.

An intractable problem arose with the plotting routines. While perfect plots were produced on TEKTRONIX 4010 screen-based equipment, the generation of the same plots on the CALCOMP 1036 drum plotter failed. An apparent source code inconsistency between these two plotting units was investigated. Some subtle coding changes solved the problem, but only after a week's effort. It was found that for consistent results, a revised co-ordinate system must be used when coding SATURN networks for Melbourne.

Overall the installation was relatively straight forward and forgiving of error. The programs require minimal computer resources, and ran quickly on the Authority's IBM 3083E processor.

TEST AREA

The Bell Street and Banksia Street corridor situated in Heidleberg, (a suburb of Melbourne) was chosen for analysis with SATURN. This is a small residential area of detached dwellings, plus shopping streets and two major hospitals. Due to lack of continuity of east-west routes, plus shopping activities in the area, congestion occurs in both Bell and Banksia Streets. To alleviate current congestion, several traffic management measures and a short new road link have been proposed. These proposals have been documented in previous studies. Figure 1 shows the more significant routes in the area, and the SATURN network used.



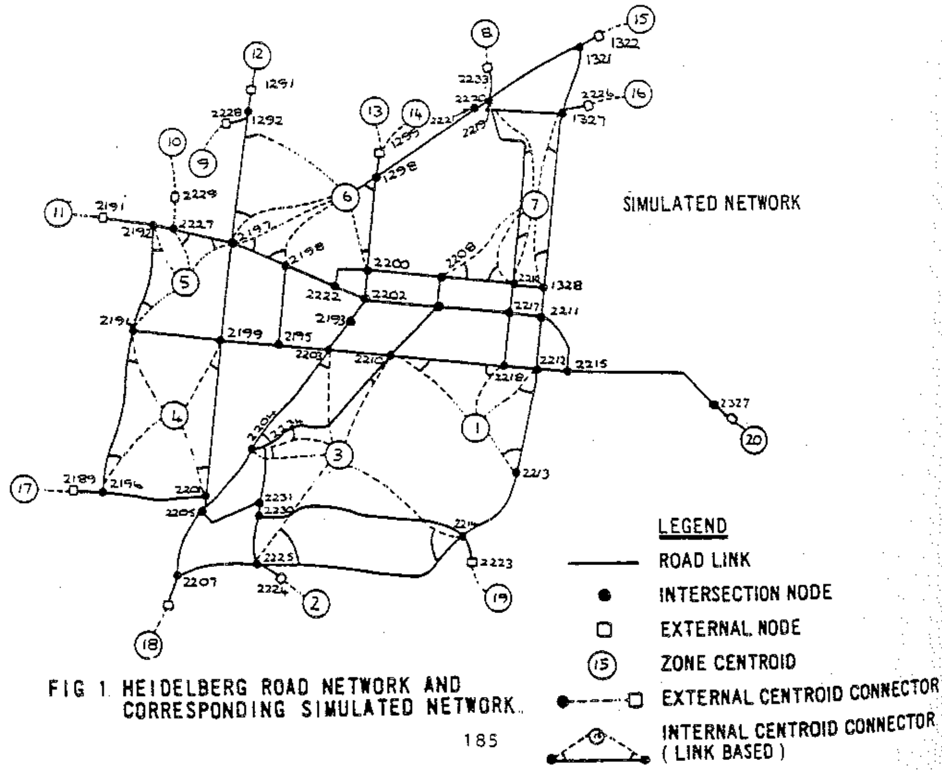


FIG 1. HEIDELBERG ROAD NETWORK AND CORRESPONDING SIMULATED NETWORK.

The UTPS program NAG was used to derive a small area network and trip table for the study from the large metropolitan - wide Melbourne UTPS model used by the RCA. NAG produced a 32 node network, connected to 14 external nodes, each representative of the rest of the metropolitan area. This network established node number, distances, and co-ordinates for SATURN. The trip table that NAG produced had to be manually entered into SATURN due to differing format requirements. No easy way was immediately seen to automate the process.

For each intersection in the study area, an extensive set of input data was required. Measurements were needed for the saturation flow for each movement, from each approach lane at all intersections, thus necessitating determination of lane width, parking and adjacent land use. For signalised intersections, the stage and intergreen times were required for all movements, plus the offset to the base time for co-ordinated installations. Travel times between intersections, traffic counts, and bus routes and frequencies were also determined. The coding of all of this information was lengthy but straightforward.

BELL-BANKSIA RESULTS

The study area base case was accepted by program SATNET and a traffic assignment produced. Following correction of some minor coding errors, the multiple combination of simulation and assignment programs was run to produce traffic volumes of reasonable magnitude for the study area. The model output data includes hourly one-way link volumes, queue size at intersections, link delays, speeds, times, capacities, lanes, distances and costs.

To refine the trip matrix, program SATME2 was used to correlate observed traffic counts to assigned traffic volumes. Using this ME2 model, the initial comparison of link volumes to observed counts revealed a mean absolute error of 26%. Following 10 iterations of the adjusting program, the error was reduced to 7%. Using the new trip table, the subsequent assignment produced traffic volumes comparing closely to observed counts, as would be expected.

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A screenline analysis was made of the base case to ensure the agreement of modelled volumes with observed traffic. The following table indicates the close agreement of the flows at the screenlines.

TABLE 1. COMPARISON OF ASSIGNED AND OBSERVED VOLUMES

LOCATION	1981 AADT(1,000's)	1981 MODELLED* BASE VOLUME (1,000's)
Bell St	30	31
Waterdale Rd	16	16
Upper Heidelberg Rd	22	23
Rosanna Rd	20	20
Banksia St	45	43
Burke Rd	27	34
Heidelberg Rd	23	23
Darebin Rd	10	13
Oriel Rd	10	12

* Assumes PHF = 10

With an acceptable base case established, the effects of project improvements were tested by coding a bypass and a one-way system proposals and conducting assignments. Estimates were required of new bypass link intersection design and signal phasing, yet these estimates obviously depend on the future flow. The analysis also necessitated changes to the coding for other intersections not physically altered, but to account for movement changes involving new links.

Figure 2 shows the after volumes for the two project cases. The bypass assignment lowered Burgundy Street traffic by 50%, raised Banksia Street traffic by around 50%, with 1890 vph = 18,900 vpd on the new link. Traffic on Bell Street was largely unchanged. The one-way case involves the circulation of around 20,000 vpd.

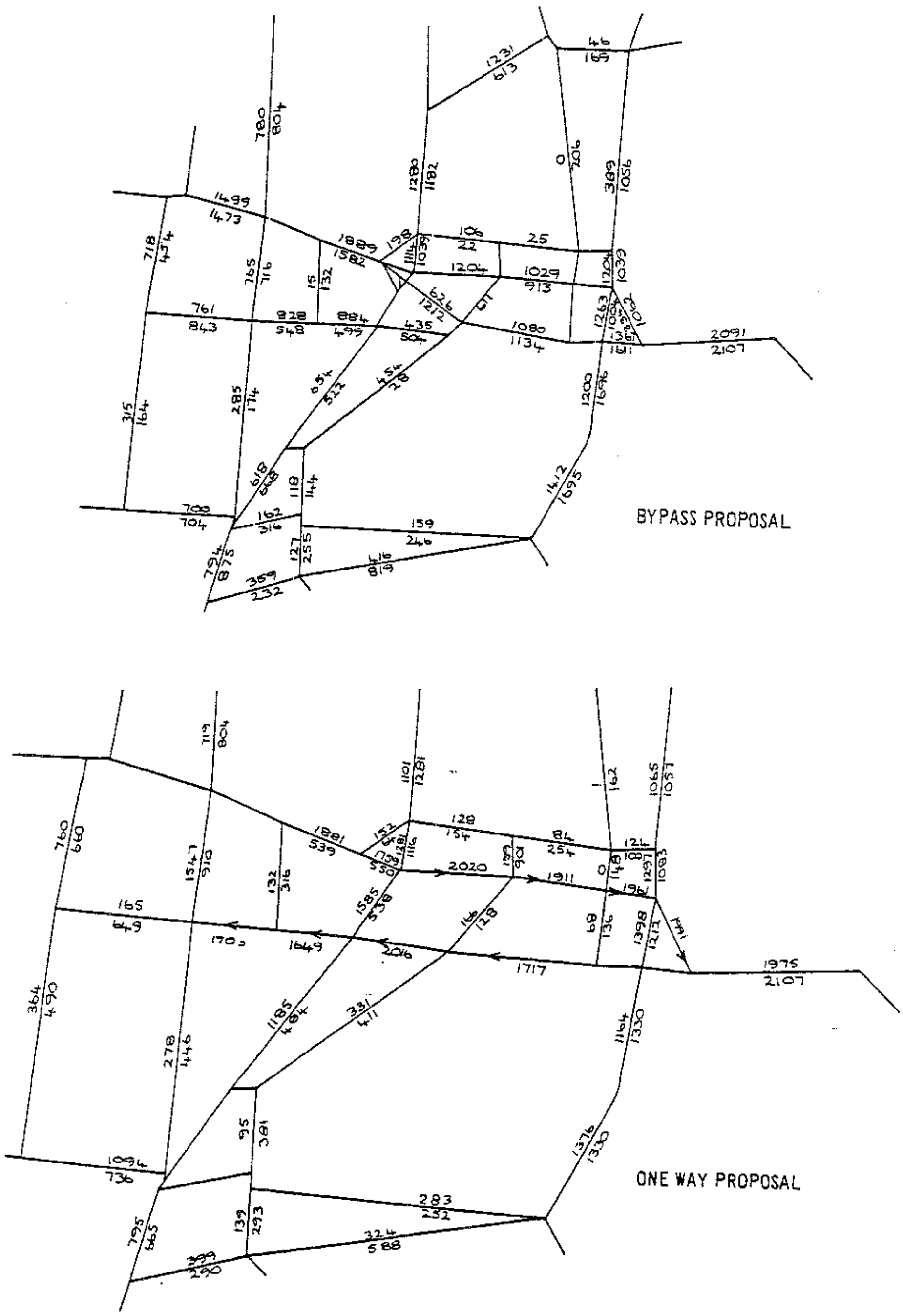

FIGURE 2 BYPASS AND ONE-WAY STREET PROPOSALS
(EVENING PEAK HOUR ONE-WAY FLOWS)

The SATURN model was found to slightly favour the bypass project over the one-way and do nothing alternatives. Table 2 depicts this favouritism in terms of parameter values. Note that the bypass case has more intersections, so that stops and fuel consumption are higher. The bypass is only very slightly favoured, with the lowest travel time and delay values. On this basis it is difficult to distinguish the merits between the base and bypass cases. However, they are preferred to the one-way street system.

TABLE 2. MEASURES OF EFFECTIVENESS FOR ALTERNATIVE NETWORKS

	BASE DO NOTHING	BYPASS	ONE-WAY	
TOTAL DELAY TIME (veh kph)	436	431	487	
TOTAL QUEUED TIME (veh kph)	710	694	822	
TOTAL FREE RUN TIME (veh kph)	935	956	954	
TOTAL TRAVEL TIME (veh kph)	2081	2080	2262	
TOTAL DISTANCE (veh kms/hr)	52016	53111	52537	
OVERALL AVERAGE SPEED (kph)	25.0	25.5	23.2	
NUMBER OF STOPS/HOUR	350701	413589	396373	
RATE OF FUEL CONSUMPTION (lph)	7446	7830	7899	
LENGTH OF TIME PERIOD	30	30	30	60

These results differ somewhat from estimates performed in a 1980 strategy study. While both studies estimated volumes of very similar magnitudes for the base and one-way system cases, in the bypass scheme, traffic diversion differences arise. For the bypass case, the strategy study predicted a significant shift of traffic to Banksia Street (34,000 vpd) to use the link, while this study predicts only 21,000. This study has a similar bypass link volume, but much more traffic remains on Banksia Street to the west. For the one-way case, the estimates are much the same.

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In the earlier study, 1991 volumes were used to assess proposals, while this analysis has utilised 1981 estimates. The 1991 volumes are around 20% higher than 1981 values, with a corresponding increase in congestion that probably supports the construction of a new bypass capacity. However, if 1991 volumes were used in the current study, SATURN would probably still not generously divert traffic to the bypass link. In fact, traffic diversion is rather difficult to calibrate with SATURN, as discussed in the following paragraphs.

A closer examination of the existing base case, compared to observed volumes, revealed some deficiencies with the initial network coding. Traffic volumes were found to be around 10% to 20% too high along Bell St, and similarly too low along Banksia Street. Little traffic was found to be turning right from Bell Street at Waterdale Road, Edwin Street, Upper Heidelberg Road or Studley Road to reach Banksia Street as occurs in practice. A selected link analysis of the 1,234 eastbound vehicles in Bell Street at the Darebin Creek, revealed that of the 730 vehicles destined to the Banksia Street Yarra Bridge, 95% remained on Bell-Burgundy-Dora, with only 5% diverted to Banksia Street before Dora Street. Clearly, the Bell-Burgundy-Dora route had been coded as too attractive in comparison with Banksia Street.

A more realistic network was established by lowering Burgundy Street speeds, and introducing pedestrian signal delays. The speeds were reduced to 40 kph in keeping with the observed low speeds caused by parking and pedestrian movements in the shopping area. All pedestrian signal installations in the study area were also coded, assuming an average five second delay to motor vehicles every minute. These changes reduced Burgundy Street traffic from 2300 vpd to 2100 vph, while also lowering Banksia Street traffic from 2200 vph to 2000 vph. While this result may seem inconsistent, the new traffic volumes all over the network became much closer to the observed values. As well, the proportion of traffic diverted from Bell Street rose to 25%.

This diversion was further increased by altering the link travel times for routes leading off Bell Street. It was found by a manual procedure that the final link travel times for three competing routes were nearly equal, so the input link speeds were adjusted proportionally for a new run of the model. This run gave a diversion of 30%, with 7% via Oriel Road and 23% on Waterdale Road. Queues along other alternative routes prevented any more paths.

Another alteration tested involved restricting capacity in Burgundy Street. Because of extensive car parking in the Street, the left lanes of the two lane intersection approaches at Cape and Studley Streets are only used for left hand turns. Previously the model permitted through movements in those lanes as well. The revised coding gave unacceptable results, as Burgundy Street traffic dropped well below observed values.

MODEL DEFICIENCIES, CAPABILITIES AND OPTIONS

Deficiencies and Capabilities

Some deficiencies of SATURN found include the large input data requirements for present and future scenarios, and an inability to assess metropolitan area wide traffic diversion effects.

Since SATURN deals with localised areas, utilising a derived local trip table and network, it cannot determine the amount of traffic drawn to this area from outside with the opening of a new traffic facility (Choraffa and Ferreira 1983).

As mentioned, extensive data is required for existing conditions, but perhaps more demanding is the need for estimates of future optimal intersection designs and signal phasing. Such estimates for a committed project could take a design section some weeks to complete, but for SATURN similar calculations are promptly required before computation.

The existing traffic signal phasing may not be co-ordinated optimally for the overall network before SATURN is applied. An optimised traffic signal scheme may be established for a network using a program such as TRANSYT and the relevant results used as input to SATURN. This method was used for providing the Liverpool test case traffic signal data (see Choraffa and Ferriera 1983). It is feasible that TRANSYT may provide a more optimal network than any measures taken with SATURN.

Unfortunately, true representation of existing traffic signal phasing is not possible using SATURN, since a common cycle time of traffic signals is assumed. Some distortion of the traffic signal phasing input to SATURN will always occur, unless of course all traffic signals operate under a common cycle time. (Version 6.1 of SATURN permits individual intersection cycle times).

When analysing a new traffic link, comparison of before and after volumes has to be completed on a manual basis, as the volume reporting program is not capable of comparing differing networks. A comparison of two networks with different link configurations, can not be handled by the program. The program can only compare identical networks, used with different trip tables for example. (However, Version 6.1 of SATURN apparently permits comparison of different networks).

Several techniques were utilised in an attempt to create "identical" networks, suitable for comparison by the plot program P1. It was necessary to be able to create networks which in certain cases would have no traffic using specified links. In these cases, such links would in reality not exist, but are required to enable comparison to other networks with the links. Techniques applied to represent these links included coding zero or low speeds, very high capacities, or traffic signal phasing that prevented movement into the links. However none of these techniques proved feasible as the SATNET program would enforce certain default values, or error messages, to circumvent such "illegal" coding.

However, a degree of success was achieved by coding the unwanted links as bus-only routes, with no assigned buses. Unfortunately, using version 4.0 of the package, SATNET prohibits the use of more than 20 bus-only links. It was thought possible to upgrade this default maximum, however our attempts to increase the value to 50 resulted in the loss of node co-ordinate values, presumably due to an exceedance of SATNET common block storage arrangements.

Using up to 20 bus only links and turns, a visual comparison was made of plotted link flows between the base network without coded bus only links and turns (original base network), and the base network with coded bus only links and turns. It was found that link flows differed somewhat between the networks. This difference was greatest in the region where modifications were made to the network. At nodes distant from these 'altered' nodes, the link flow differences were negligible, (see Figure 3). The differences of link flows between networks is not comparatively large; both networks record flows of similar magnitude on each link. No explanation for these differences is readily apparent, save that the bus only links may introduce some intersection delays due to default parameter values inherent in the model. These links have traffic volumes which differ significantly from what would be expected.

While SATURN allows plots of link speeds, times, distances and costs, it does not enable summary printouts of these same parameters. Thus it is very difficult to confirm plotted values. However, flows and capacities can be both plotted and printed.

Although SATURN is a detailed simulation model, it does lack a variety of modelling techniques found in the UTPS and Planpac packages. The following table shows the respective abilities of UTPS and SATURN to undertake various techniques.

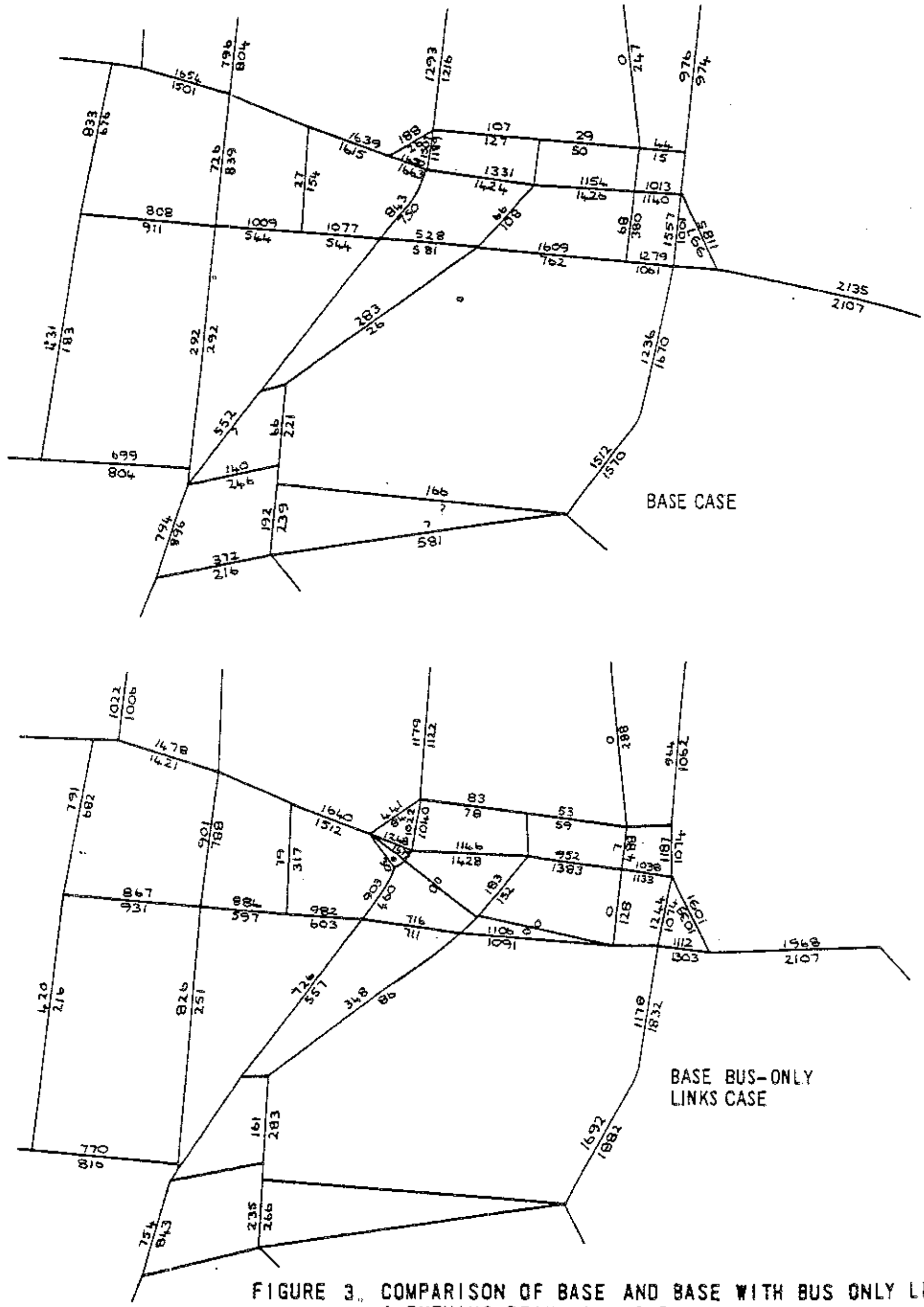

FIGURE 3. COMPARISON OF BASE AND BASE WITH BUS ONLY LINKS
(EVENING PEAK HOUR ONE-WAY FLOWS)

TABLE 3, COMPARISON OF UIPS AND SATURN CAPABILITIES

TECHNIQUE	UIPS	SATURN
Network Comparison	Easily accomplished with program COMPHR.	Normally not permitted, if networks differ unless bus-only lanes are used to ensure networks are equivalent for program P1.
Plot network parameters and trees	PLOTGE will plot any parameter.	Very limited range of parameters plotted by P1, and no trees.
Correlate traffic counts to the trip matrix	No program, but achievable with UMATRIX.	Easily performed with SATME2.
Manipulate matrices.	Performed with UMATRIX	Performed with M1 to M6.
Modify historical record to include non-standard fields.	Use HRMOD	Not possible
Selected link analysis	UROAD provides this capability, based on the last iteration only.	SATASS provides zone to zone trip proportion for each selected link, from the last iteration.
Estimation of road user costs	Use LNKCST	Not possible, although could be achieved manually using relevant output provided by SATURN.

Model - Options

Using the accepted model, the influences of cycle time, simulation time units, simulation iterations, assignment iterations, model iterations, time period, and loop counters were studied. As described in the following paragraphs, only the loop counters were found to have vital influence.

The common traffic signal cycle time parameter LCY did not vary flow and queue conditions greatly. This is probably because the signals in the network do not operate under a common cycle time. However, traffic is modelled in cycles by SATURN. As a test, all of the modelled signals were re-phased to a 60 or 120 second cycle time, but only a marginal improvement to flows and queues occurred.

The number of time units into which the cycle is divided for the simulation, parameter NUC, does not greatly affect conditions as long as it is at least five or larger. A large NUC value ensures proper modelling of traffic platoons from signals, at the expense of computer resource time. A value of one was found to be inaccurate, while values from five to ten are probably optimal.

The maximum number of simulation iterations, parameter NITS, was found to not alter results significantly. In the test runs, the number of simulation iterations performed always equalled NITS, indicating that the criterion for the cessation of iterations was not met. This criterion is not evident in the documentation. Nonetheless, flows and queues altered little with increasing iterations. The NITS default value of 6 is probably sufficient.

The maximum number of assignment iterations, parameter NITA, had similar non-effect. The assignment will terminate at NITA iterations, or according to other criteria associated with Wardrop's First Principle. If NITA exceeds ten, the other criteria will generally terminate the assignment.

The duration of the time period considered (LIP) should equal at least an hour. This time allows all vehicles to enter the network. For LIP values of 60 and 120 minutes, results were similar.

The parameter MASTER must be specified to count the number of assignment-simulation loops, up to the maximum number of loops, MASL. MASTER must be incremented and specified for each successive loop, otherwise the model does not average results from previous iterations, leading to inaccuracies. This fact was not documented at all well in the manual, and significantly delayed test analyses. Some five assignment simulation loops are required for accurate results. The following table shows the influence of successive loops.

It can be seen that link volumes change little with increasing loops, as observed on volume plots, but queues and intersection conditions become more optional.

TABLE 4. ASSIGNMENT CONVERGENCE STATISTICS

FINAL SUM OF ASSIGNMENT FLOW*TIME(VHPH)	ASSIGNMENT VEHICLE HOURS		% OF ASSIGNED FLOWS WITHIN 5% OF PREVIOUS VALUE	SIMULATION TRAVEL TIME(VHPH)	SIMULATION FUEL(LPH) CONSUMPTION
	ON LINKS	IN TURNS			
2279	1113	1165	-	2255	4023
3804	1111	2693	32	?	?
4260	1110	3139	63	2095	3794
4382	1114	3260	65	2084	3830
4508	1113	3379	66	2080	3915

A final improvement was achieved by recoding all centroid generated traffic to enter the network at dummy nodes, rather than at link junctions. This technique provided much the same traffic volumes, but substantially reduced queueing, stops and delays at link junctions. A dummy node introduces no delays at all to traffic, while other node junction types do and thus give slightly worse results.

However, it was disturbing to find that the addition of pedestrian signals reduced the number of stops, while increasing delays and travel time. A closer examination revealed that only signals connected to centroids reduced stops. If signals not connected to centroids were alone introduced, stops increased along with delays and travel times, as would be expected. Presumably, with centroid traffic input, pedestrian signals break up vehicle platoons, thus lowering overall stops.

CONCLUSIONS

While straightforward to use, SATURN has significant input requirements and lacks some capabilities. The SATURN package is easy to establish, but has no cross-referenced documentation for output analysis. Extensive network input data is required for present and future scenarios. While SATURN provides adequate assignment capabilities, it lacks many of the specialist result analysis techniques available in UTPS, particularly network comparison.

While the model is readily calibrated with existing flows, refined results from SATURN are difficult to obtain as the model depends significantly upon centroid connection location and link speeds. Traffic diversion effects are not readily handled. It would seem that SATURN is not suited to studies involving major network changes, but is applicable to traffic management measure investigations. Its applicability to the Bell-Banksia study is somewhat limited.

It is recommended that future SATURN runs incorporate pedestrian signals, with centroids connected to dummy nodes, in order to better distribute entering traffic. Improved estimates of traffic speed need to be determined.

The model did not conclusively support the construction of the Bell-Banksia Bypass, and seemed to dismiss a one-way street system. However, it did verify traffic volumes that were previously estimated.

ACKNOWLEDGEMENTS

This paper is presented with the permission of Mr T H Russell, Managing Director and Chairman of the Road Construction Authority, Victoria. The views in the paper are those of the authors and do not necessarily represent those of the Road Construction Authority. The authors wish to thank the RCA and Word Processor Operator, Miss Anna Maria Minnella.

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