Published paper
Simon Shepherd (1995) *Area Speed Flow Relationships: Initial SATURN Results for the Ring-Radial Network*, University of Leeds, Working Paper 450

UNIVERSITY OF LEEDS
Institute for Transport Studies

ITS Working Paper 450 *ISSN 0142-8942*

December 1995

AREA SPEED FLOW RELATIONSHIPS : INITIAL SATURN RESULTS FOR THE RING-RADIAL NETWORK

S. P. SHEPHERD

This work was undertaken on a project sponsored by the Engineering and Physical Sciences Research Council.

Preface

This paper is one of a series of ITS working papers and technical notes describing the methodology and results of the EPSRC funded project "The definition of capacity in urban road networks : The role of area speed flow relationships". The objectives of the project were to investigate the interaction between vehicle-hours and vehicle-km within a network as the demand for travel increases; to develop improved area speed flow relationships; to use the relationships to explain the process by which networks reach capacity; and to assess the significance for the evaluation of road pricing policies.

The approach used was to collect the vehicle-hours and the vehicle-km directly from a simulation model and thus create relationships between supply and demand in terms of veh-hours/hr and veh-km/hr demanded and also between times per trip and trips demanded.

During the project two models were used. The first was a micro-simulation model called NEMIS. This model was used on hypothetical networks ranging from single link to a six by six grid and finally a ring-radial network. The networks were used to study the effects of changes in OD pattern and the effects of varying capacity on the resulting speed flow measures.

The second model used was SATURN. This model was used to study the same ring-radial as before and a full SATURN model of Cambridge. The SATURN results were then taken one step further in that they were used to create an aggregate model of each network using SATURN in buffer only mode. The related papers discuss issues such as network aggregation. Note that the methodology and terminology was developed as the study progressed and that in particular the method varies between application of the two distinct models.

The reader is directed to the attached appendix A for a full list of publications arising from this project.

1. Introduction

This paper presents the initial SATURN results for the 9 zone ring-radial network described by Shepherd (1995a). The relationships are taken directly from running the SATURN assignment and simulation process until convergence for various levels of demand. The four basic relationships developed for the NEMIS methodology (Shepherd 1995b) are presented for the central zone 1, the inner quadrant zone 2 and the outer quadrant zone 6. The relationships are compared with those obtained by NEMIS simulations for the base matrix A (Shepherd 1995a).

1.1 Definitions

The aggregate link types used were the same as for the NEMIS study and were coded using link capacity indices. Figure A shows the SATURN representation of the ring-radial and the associated codes used for aggregation of data by area (zone) and direction. N.B. these codes are also used in the figure titles.

The curves may be compared to the NEMIS generated curves (Shepherd 1995a) although it should be noted that the demanded flow axis may be different due to a different set of routes at free flow conditions. Also note that for SATURN we have two sets of orbital routes distinguishing between clockwise and anti-clockwise which means the demand is roughly half that of the NEMIS orbital links.

The SATURN results are taken from the simulation output aggregated by link indices. The SATURN simulations were each run for one hour. The output is split into two periods, the first period reports data for the first hour, the second period is of indefinite length and estimates the conditions for any demand which cannot be serviced in the first period.

Hence for the usual four measures, the actual flow (vehicle-km/hr) is taken from the vehicle-km performed in the first time period. Similarly the vehicle-hours and hence speed performed is taken from the first time period. The second time period is used by any over-capacity flow which is displaced beyond the first hour. The supply speed and time/km versus demanded flow are taken from periods one and two together.

These definitions differ slightly from the NEMIS slice and tracking approach in which the slice approach gives performance measures while the tracking approach gives supply measures. In the SATURN approach the first period gives performance measures, while the first plus second gives an approximation to the supply measures.

Another difference in modelling approach is in the assignment procedure. NEMIS used en-route diversion as congestion built up whereas SATURN uses a complete assignment for each demand level simulated. The SATURN results converged between assignment and simulation loops for the first seven demand levels (95% of links changing flows by less than 5%), demand levels 8,9 and 10 gave lower convergence statistics. The last points although not converged did not give different results from one iteration to the next in terms of total flow and total times for the network and were extremely congested.

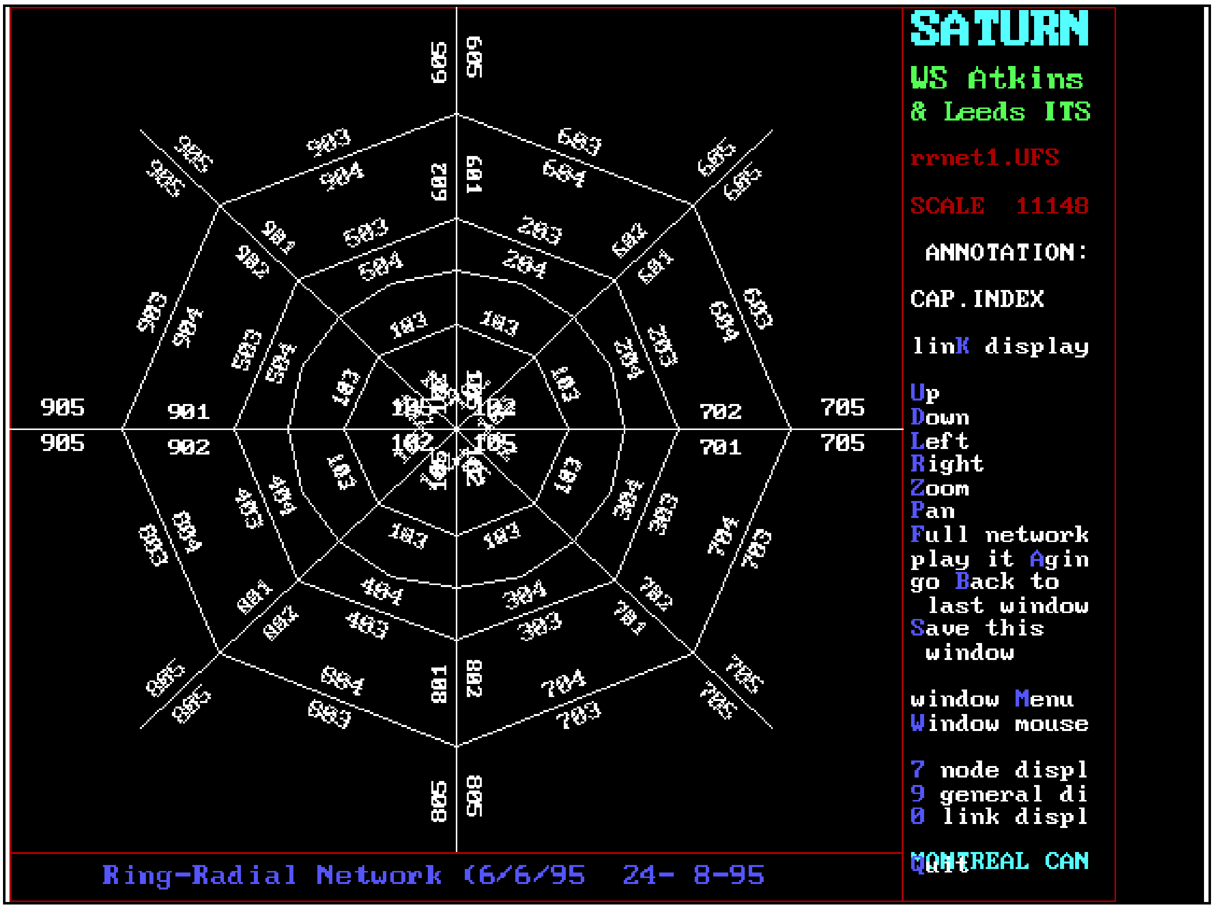

Figure A: SATURN Ring-Radial Network

2. Comparison of Results

Note that only the speed flow performance measures are directly comparable between NEMIS and SATURN simulations. For the NEMIS figures refer to Shepherd (1995a).

2.1 Total Network Measures

The speed versus flow performance curves differ in that SATURN gives a higher capacity flow than NEMIS (36k veh-km/hr compared to 25k veh-km/hr in NEMIS) although both give a final speed of 4 km/h. The free flow speed in SATURN is 40 km/h compared to 35 km/h in NEMIS but the gradient is greater in SATURN in the lower flow conditions (i.e. there is a greater drop in speed for a slight increase in flow from free flow conditions in SATURN). The NEMIS curve shows a slight bend-back of the performance curve not present in SATURN.

The speed versus demanded flow curve uses the same definition of speed for SATURN with the addition of the results for period 1+2 as described above. The supply speeds in NEMIS were based upon the tracking approach and hence give lower final speeds. The demanded flow axis is defined in the same way for SATURN as it was for NEMIS i.e. the vehicle-km/hr taken from the lowest demand level multiplied by the trip matrix factor. In general the shapes of the speed and time/km supply curves are similar but the congested points give higher speeds in SATURN. Although the demanded flow axis is defined for the SATURN routes at free flow these flows are not too dissimilar to those in NEMIS.

There is a major difference in the actual flow versus demanded flow curves in that the SATURN flow reaches a capacity (higher than NEMIS) and maintains this flow whereas in NEMIS the flow falls as demand increases. The SATURN results are taken from period 1 and therefore are more consistent with the time-slice or performance results which fall a little but then maintain the flow.

2.2 Links 102 (Zone 1 outbound) (figs 5-8).

These links include external queues on the entry links.

The NEMIS performance curves bend-back completely to the origin implying that these links become totally blocked. SATURN on the other hand maintains the demanded flow, which is the same as for the NEMIS simulations, for all levels.

Figure 5 shows a linear relationship between speed and flow until demand level 6. Period 1+2 gives slightly higher times/km than period 1 alone.

In SATURN the entry links are modelled with vertical stacks of queues at the stop line. Traffic is loaded directly onto this queue and so travels the full link length; this means that traffic flow in veh-km/hr continues to rise with demand as shown in figure 8. Subsequent papers regarding SATURN analysis ignore all entry and exit links.

2.3 Links 103/104 Orbitals (clockwise and anti-clockwise figs 9-16)

These links do not have external queues.
For the NEMIS simulations there was no distinction between clockwise and anti-clockwise flows. Therefore adding the lowest SATURN flows for 103 and 104 gives the equivalent flow in NEMIS i.e. the same demanded flow at free flow conditions. Again the orbital curves in NEMIS display bending-back with a total capacity of around 4000 veh-km/hr whereas in SATURN the maximum flows add up to 3300 veh-km/hr for 103 and 104. The 104 anti-clockwise orbitals display some bending-back (figure 13) perhaps due to a reduction in the number of right turners as congestion increases. The clockwise links' performance curve (figure 9) does not bend back.

The difference between the SATURN and NEMIS supply curves is mainly due to the fact that NEMIS predicts a near gridlock situation for these links. There is obviously going to be a difference in the effect of blocking-back between models but also the re-assignment procedure in NEMIS is en-route compared to the full assignment in SATURN for each demand level. This could limit the flow on these links in SATURN. It is difficult to say from these curves whether the flow was restricted by the assignment or by the capacity of the orbitals being reached as suggested by figures 12 and 16.

2.4 Links 201 Inbound (figs 17-20)

There are no external queues for these links.

Both SATURN and NEMIS (re-assigned curves) produce some bend-back on the speed flow performance curves. The curves give similar capacities and have a similar range of demand. There is a sharper change from free-flow to congested regime with NEMIS, SATURN speeds dropping smoothly with increased flow. For high demands both supply curves level off with a time/km of around 0.3 hours/km.

2.5 Links 202 Outbound (figs 21-24)

There are no external queues for these links.

Again both NEMIS and SATURN have similar capacities although the NEMIS speed flow curve does bend back whereas the SATURN curve is almost linear until capacity is reached. The time/km supply curve in SATURN actually drops as demand is increased, however these points are not fully converged on a link by link basis. The congested speeds are similar in NEMIS and SATURN.

2.6 Links 203/204 Orbitals (figs 25-32)

These links contain some external queues.

When added together the SATURN orbitals give a similar speed flow performance curve to NEMIS. The supply curves are also similar but the demand is scaled by a half. There is a slight difference between the anti-clockwise (204) and clockwise (203) links in that the anti-clockwise links have a higher flow for the same demand level. Figures 28 and 32 show that extra flow has been assigned to these orbital routes compared to the free flow routes as demand increases.

2.7 Links 601 Inbound (figs 33-36)

These links have external queues.

SATURN gives the same demand range as NEMIS. The main difference is that the NEMIS speed flow curve bends back after reaching a capacity of 1100 veh-km/hr whereas SATURN reaches a flow of 1000 veh-km/hr and then the flow increases without a significant drop in speed. SATURN maintains the demanded flow on entry links as described in section 2.2 causing a bias in the performance curves.

2.8 Links 602 Outbound (figs 37-40)

These have no external queues.

These links maintained a relatively high speed in NEMIS and the flow dropped as demand increased due to congestion or blocking-back in the central zones. In SATURN the free-flow regime is maintained until the flow reaches 300 veh-km/hr then there is a sudden drop in speed and capacity is maintained at around 430 veh-km/hr.

2.9 Links 603/604 Orbitals (figs 41-48)

These links have no external queues.

The demanded flows of 603 plus 604 are less than the NEMIS orbital demand. However in SATURN there is a lot of reassignment of flow to these orbitals compared to the free flow routes (see figs 44 and 48). The speed flow curves display bending-back for the clockwise orbitals but show a higher capacity than the anti-clockwise orbitals. The supply curves for time/km give a similar shape to the NEMIS orbital.

3.0 Conclusions

In general SATURN produces smooth supply curves of speed and time/km versus demanded flow. The curves react to increases in flow more rapidly than NEMIS curves in the free-flow regime but NEMIS then has a sharper cut-off at capacity.

The speed flow performance curves produced by SATURN can exhibit some bending-back but not so much as the NEMIS curves for this particular network. The bending-back in SATURN is due to built in dependencies such as opposed turns and the blocking-back factor.

Entry links in SATURN maintain the demanded flow as all demand is fed directly to the stop line on the entry links. In all subsequent analysis both entry and exit links will be ignored.

Overall the SATURN supply curves seem reasonable as area speed flow curves. The performance curves differ from the NEMIS performance curves in some cases usually under congested conditions which is expected due to the differences between the modelling approaches in SATURN and NEMIS. This difference can also be fed through to the higher demand levels of the supply curves, but neither NEMIS nor SATURN has been calibrated under such congested conditions.

References

Shepherd, S.P. (1995a) Area speed flow relationships : Results for the 9 zone ring-radial network using NEMIS. ITS Working Paper 447, Institute for Transport Studies, University of Leeds.

Shepherd, S.P. (1995b) Area speed flow relationships : Definition of data collection methodology. ITS Technical Note 383, Institute for Transport Studies, University of Leeds.

Appendix A: Area Speed Flow Publications

May, A.D. and Shepherd, S.P. (1996) Area speed flow relationships and network aggregation. Urban transport forum 96 Barcelona, Spain 2-4 October 1996.

May, A.D. and Shepherd, S.P. (1996) Area speed flow relationships and strategic models. Proceedings ISATA96 Florence, June 3-6th 1996.

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May, A.D. and Shepherd S.P. (1994) Area Speed-Flow Relationships By Micro-simulation : Grid Networks. ITS WP429 Dec.94.

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Shepherd, S.P. (1995) Area Speed-Flow Relationships : Summary of the 9 zone ring-radial results using NEMIS. ITS WP447 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : The effects of dependency and reassignment using 2 link networks. ITS WP448 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : The effect of varying signal capacity. ITS WP449 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : Initial SATURN results for the ring-radial network. ITS WP450 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : Ring-radial network aggregation using SATURN. ITS WP451 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : Aggregation by movement type for the ring-radial using SATURN. ITS WP452 Dec.95.

Shepherd, S.P. (1995) Area Speed-Flow Relationships : Aggregation of the Cambridge SATURN network. ITS WP453 Dec.95.

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Technical Notes

Shepherd S.P. (1995) Area Speed-Flow Relationships : Considering their future use in START. ITS TN361 Jan 95.

Shepherd S.P. (1995) Area Speed Flow Relationships : Definition of Data Collection Methodology. ITS TN383 June 1995.

Shepherd S.P. (1995) Area Speed Flow Relationships : Initial Ring-radial results using NEMIS. ITS TN384 November 1995.