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AREA SPEED FLOW RELATIONSHIPS : THE EFFECTS OF DEPENDENCY AND REASSIGNMENT USING 2 LINK NETWORKS

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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

The effects of dependency and reassignment on the area speed flow measures can be separated and studied using the two link networks shown in figure 1(a) and (b). The priority junction will be used to show the effects of dependency, the minor arm measures being dependent on the major arm flows. The signalised intersection with two routes will be used to explain the effects of reassignment on the speed flow measures. These general effects will be useful in analysing the more complicated results from the ring-radial network.

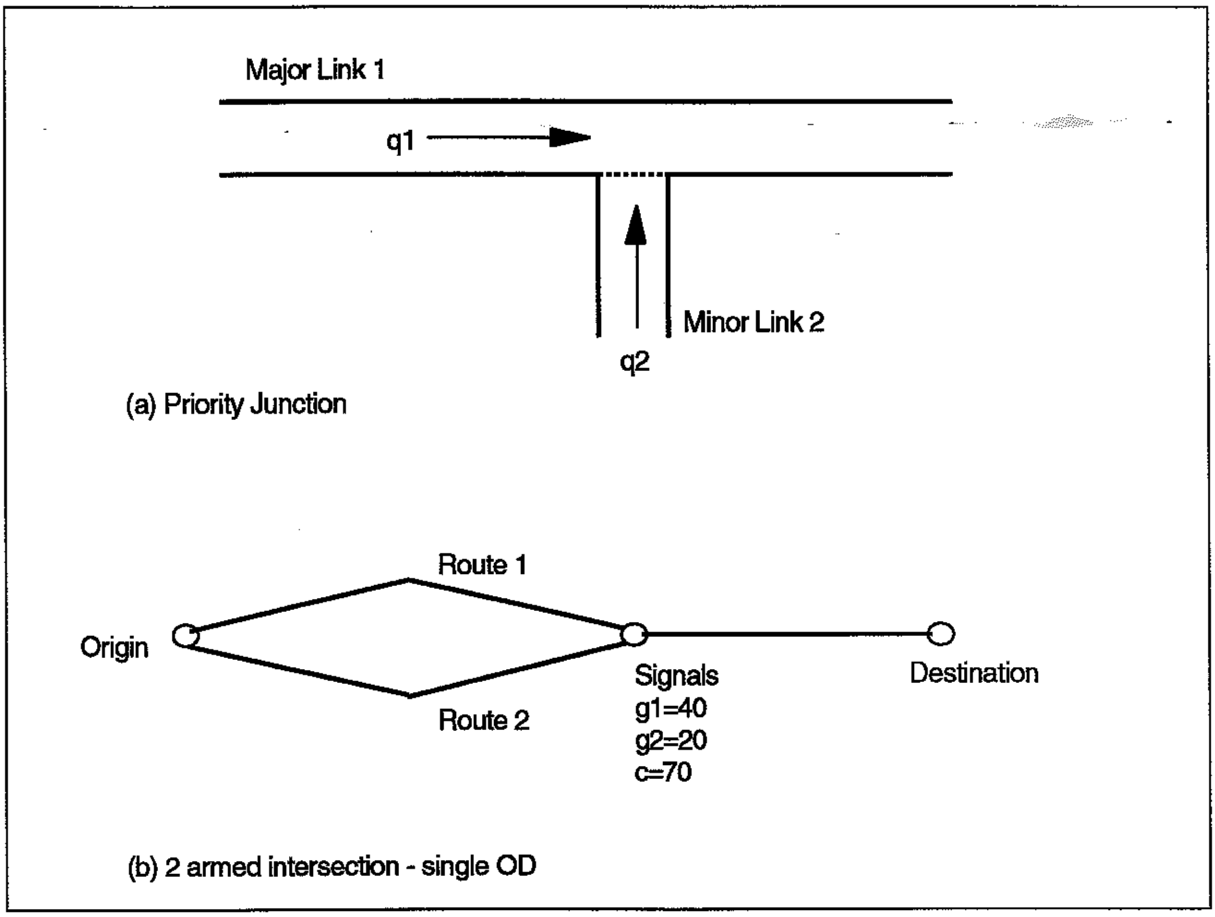


Figure 1. Two Link Networks

1.1 Link Dependency

The priority junction shown in figure 1(a) consists of two single lane links both 2.5 km in length approaching a priority junction. The network was simulated for two origin destination matrices as follows :-

OD1 : major link flow equals minor link flow ($q_1 = q_2$)
OD2 : major link flow is double minor link flow ($q_1 = 2q_2$)

Figures 2+3 show the supply speed versus demanded flow for links 1+2 for both OD matrices. For figure 1 the curves are similar for both OD flows apart from the last point for OD1 which seems spurious and will be discussed later. The curve for OD2 covers a wider range of demand as the flow is double that of OD1 for each simulation.

The curves for link 2 are significantly different from each other even though the flow demanded is the same for this link for both OD matrices. The minor link is affected by the flow on the major link (as it must give way). As the flow on link 1 is doubled (OD2) then the capacity of link 2 is reduced resulting in a shift in the curve for the same demanded flow.

Figures 4+5 show the actual flow versus demanded flow for both links. Again the last point for OD1 seems spurious but the flow through the junction as a whole (link 1+2) at capacity is 4500 veh-km/hr for both OD matrices. In the OD2 case the flow on the minor arm is reduced to zero as the major flow is increased. The last point for OD1 suggests that the minor arm suddenly improves as the demand is increased. This is thought to be some strange error in the gap acceptance technique and needs further investigation. Note that it does not occur for OD2 when the major arm flow is double the minor arm flow.

Figures 6+7 show the performance speed (within the physical links) versus actual flow for OD2. The major link remains at a high speed even at capacity of 4500 veh-km/hr, whereas the minor link shows the classic bending-back curve of a link which is being blocked as demand is increased. The drop in speed for the fourth point on link 1 suggests that the flow is affected by the flow which enters from the minor link so that at some points the flow or speed on link 1 is dependent on the flow on link 2 (which can enter the major route). As the flow on link 1 increases further then the flow on link 1 is reduced to zero and the speed of the flow on link 1 is uninterrupted at capacity. This sort of dual dependency could explain the last spurious point for OD1.

1.2 Dependency Conclusions

This simple example shows firstly how one link speed flow curve can be dependent on the state of another link and secondly how a simple change in OD pattern can change the form of that dependency resulting in a shift in the speed versus demanded flow measures. The physical speed flow performance curve of link 2 in the above example changes as the OD pattern is changed.

This type of change can be produced by other forms of congestion within NEMIS e.g. blocking-back at signalised intersections which is the case for the grid and ring-radial networks. Any shift in curves for these networks may be due to a change in OD pattern resulting in a different congestion pattern with different dependency relationships between certain links i.e. changing the physical speed flow performance curves.

2. Reassignment

The effect of reassignment is illustrated by considering the 2 route (2 link) network in figure 1(b) with a single origin destination pair. Suppose that the signalised junction originally gave equal green times to each route so that the long term assignment of demand would be to split the flow 50% on each route. Now consider the effect of changing the signal settings so that route 1 receives 40 seconds of green, route 2 receives 20 seconds of green with 10 seconds lost time. Obviously the long term reassignment would be for a split in flows of 67% on route 1 and 33% on route 2. However to see the effect of reassignment we now begin the simulations with the previous assignment i.e. 50/50 split.

As the demand is increased then the difference in costs between the routes should provoke a reassignment to link 1, the higher capacity route. In NEMIS this is modelled as a response to congestion or en-route diversion which can be switched on or off. To compare the effect of reassignment three cases were run as follows :-

1. 50/50 RA. Starting with a 50/50 split between routes for each simulation i.e. equal demand for each route and allowing the en-route reassignment process.

2. 50/50 Fix. Starting with a 50/50 split between routes and keeping the split constant i.e. fixed route for each simulation.

3. 67/33 RA. Starting with the correct split for each simulation obtained by running the NEMIS static assignment routine before the simulation stage and allowing en-route diversion.

This last case is the way in which NEMIS would normally be used when a change in signal settings or OD matrix is to be simulated. It is included in the following analysis to show how close the en-route diversion alone can react to the congestion. Note that the demanded flow axis is based upon the assumption of equal demands for each route i.e. a 50/50 split so that for case 3 the x-axis is false.

Figures 8+9 show the speed versus demanded flow for each link for all 3 cases. The reassignment process shifts the curve from the fixed route case for link 1 decreasing the speed for the same demanded flow. It appears close to the 67/33 RA case but remember that for this curve the x-axis should be scaled up by a factor of 67/50. For link 2 the difference between fixed route and the reassigned 50/50 case is minimal but in the right direction.

Figures 10+11 show the actual flow versus demanded flow for both links for all three cases. Figure 10 shows that flow is diverted to route 1 as the demand is increased and the actual flow is greater than that demanded. The flow is tends towards that generated by case 3 for link 1. For link 2 the reassignment is less pronounced, in fact it can be seen that the flow subtracted from link 2 does not correspond to the flow added to link 1 for all demand levels. This is because as link 2 becomes full, with fixed routes an external queue builds up to use link 2 which does not contribute to the flow measure, however with reassignment some of the external queue is reassigned to link 1. The reassignment process does not produce a perfect long term reassignment as there is a time lag in the response to the build up of congestion.

Figures 12-14 show the speed flow performance curves for link 1 for all 3 cases. From these figures it can be seen that the performance of the link has not been affected i.e. reassignment does not change the physical performance of the link, it merely changes the separation between the points representing different demand levels within the curve.

2.2 Reassignment Conclusions

The en-route diversion process alone does not produce a long term reassignment. The static pre-assignment plus en-route diversion can produce the correct response.

Reassignment alone cannot change the performance curve of a link or area, however it can produce shifts in supply measures when the x-axis is demanded flow based upon factoring the vehicle-km/hr produced by the lowest demand level routes and flows.

3. General Conclusions

Although the above simulations were for NEMIS links (2.5 km) it could be argued that similar problems could result from the use of area measures or START links.

Two types of changes have been identified brought about by changes in the OD pattern as for the priority junction and by a simple increase in demand as in the reassignment problem.

Spatial dependency causes the performance of one link to be dependent on another link flow. A change in OD pattern can cause via this dependency relationship a change in the performance and supply curves of the dependent link or area.

Reassignment alone cannot change the performance curve of a link but it can cause shifts in the supply measures.

In a more complicated network such as the grid or ring-radial networks both reassignment and spatial dependency are acting in combination making any changes in the four network measures difficult to explain when a change in OD pattern or simply an increase in demand is simulated. A reassignment can cause a change in spatial dependency and vice-versa. Imagine if the priority junction replaced the signals in the two route case, then increasing the flow on link 1 would increase the costs on link 2 and so produce a reassignment until there was zero flow on the minor arm (in the long term).

Finally reassigned measures should be passed to the strategic model as these will include not only the effects of reassignment between areas as demand increases overall but also any changes in spatial dependencies which may change as a result of reassignment.

Fig 2

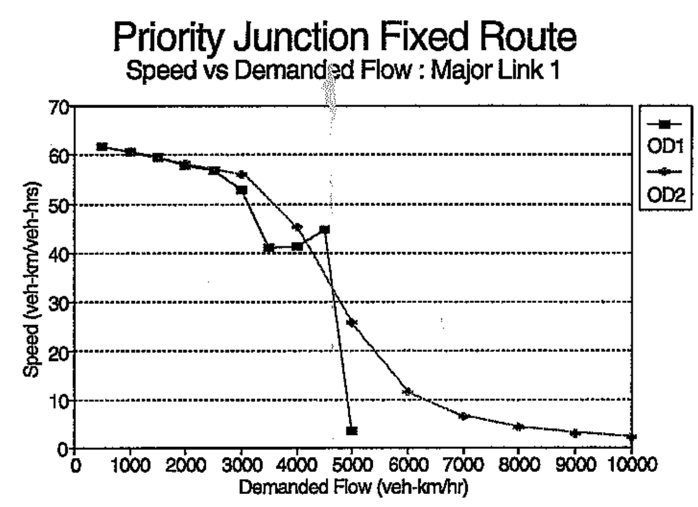


Fig 3

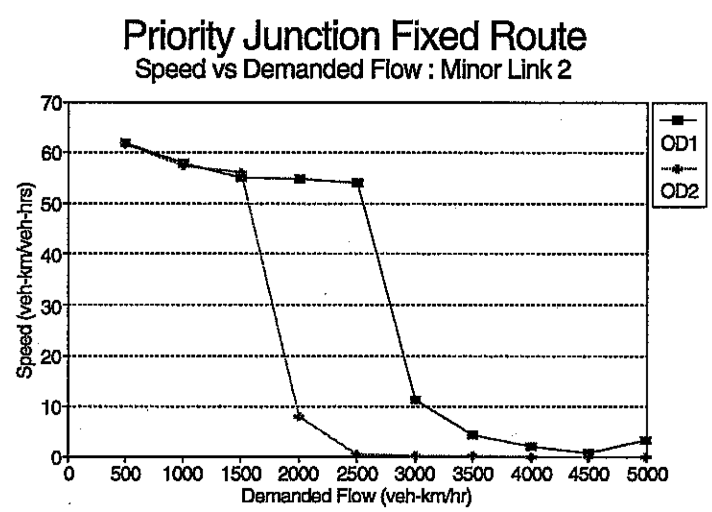


Fig 4

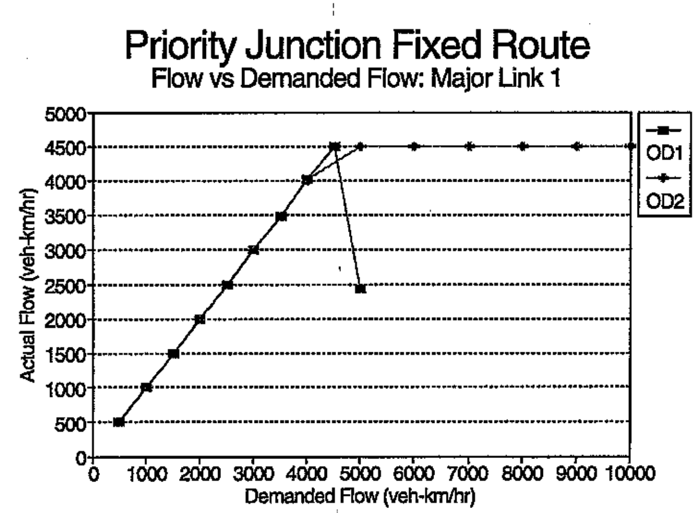


Fig 5

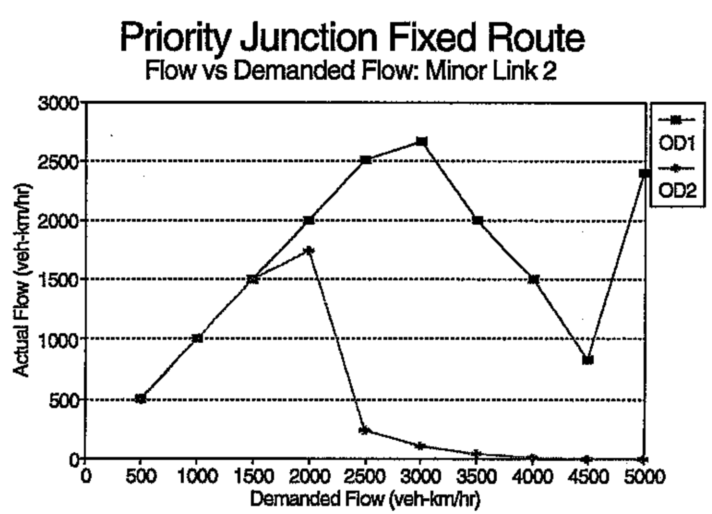


Fig 6

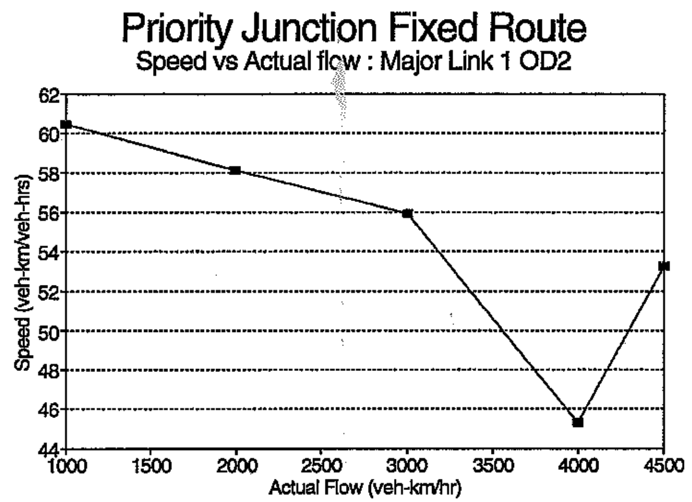


Fig 7

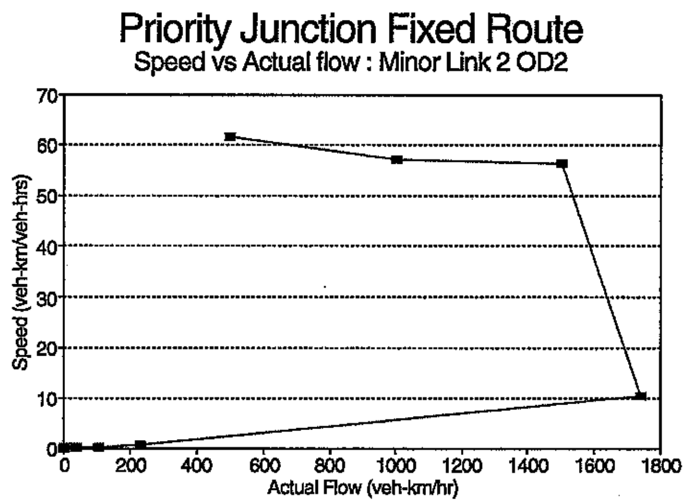


Fig 8

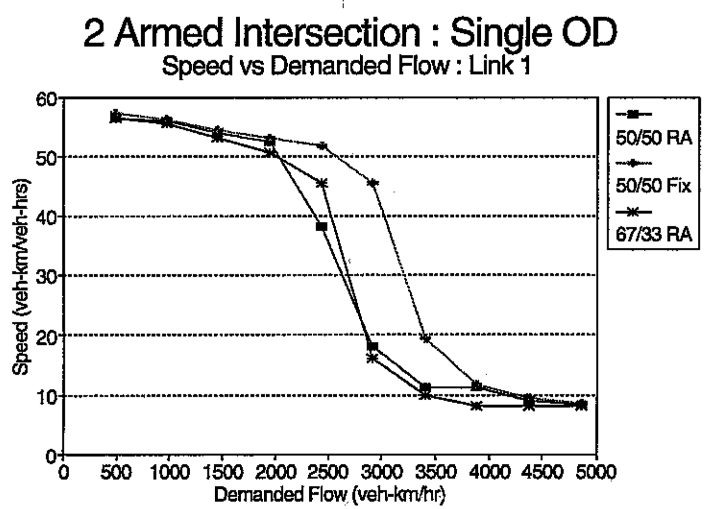


Fig 9

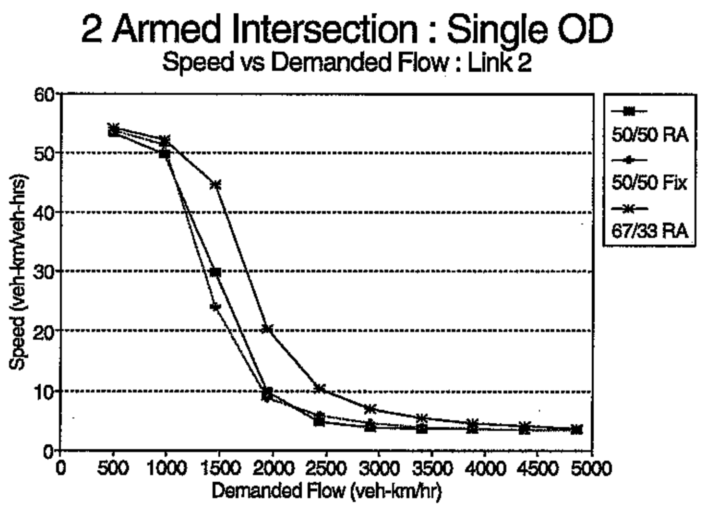


Fig 10

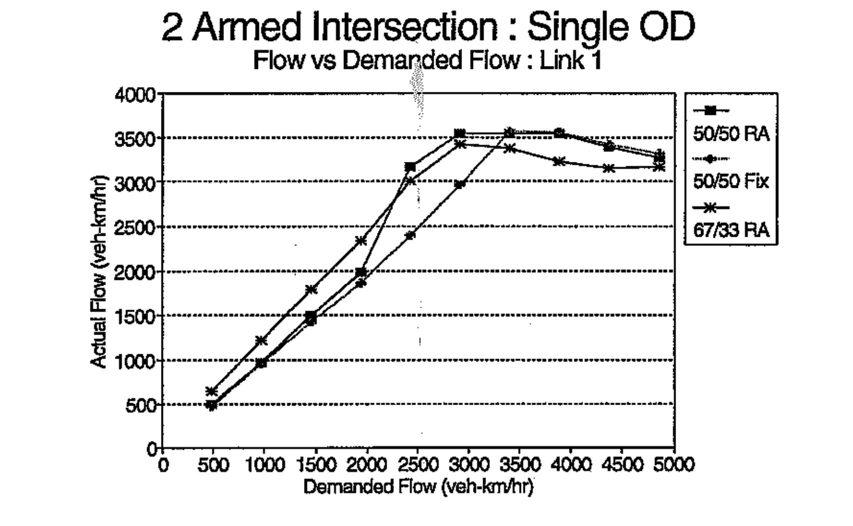


Fig 11

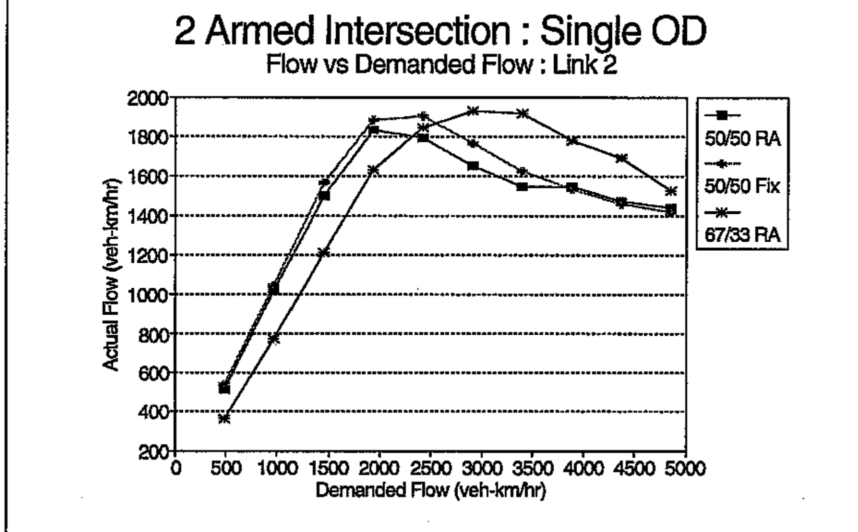


Fig 12

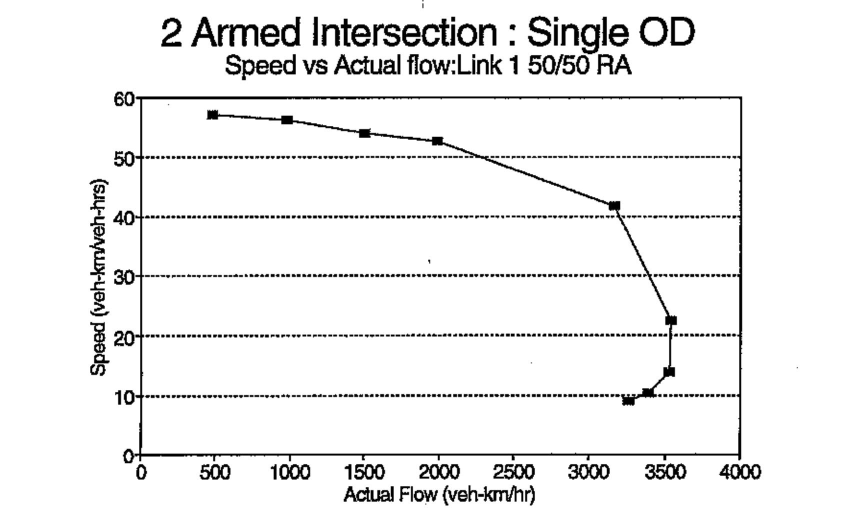


Fig 13

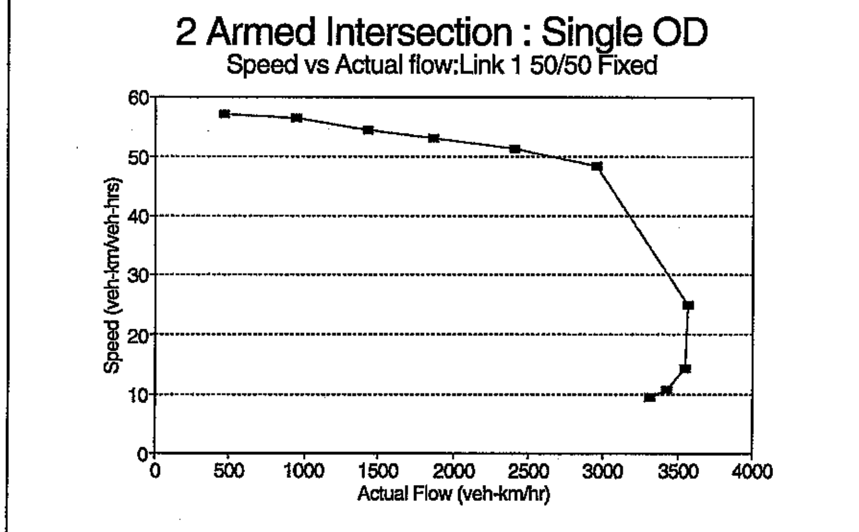
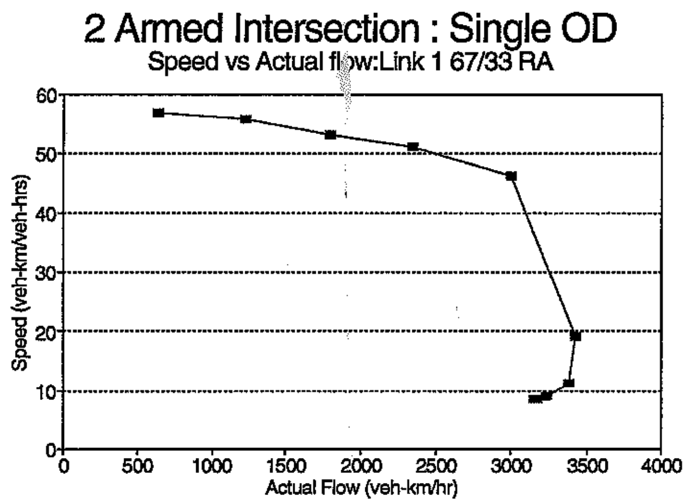


Fig 14


2 Armed Intersection : Single OD
Speed vs Actual flow:Link 1 67/33 RA
Speed (veh-km/veh-hrs)
Actual Flow (veh-km/hr)
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500
4000