

EVALUATION OF IVHS OPTIONS USING CONTRAM AND INTEGRATION

L. Rilett¹, C. Benedek¹, H. Rakha² and M. Van Aerde²

1 Department of Civil Engineering, University of Alberta, Edmonton, Alberta,
Canada T6G 3G7

2 Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada,
K7L 3N6

ABSTRACT

On going operational field tests of alternate IVHS deployments have identified a need to utilize simulation models to generalize empirical findings of different system configurations, architectures and levels of market penetration. The CONTRAM and INTEGRATION models have been utilized in Europe and North America, respectively, to develop such generalizations. A critical element in any international comparisons, of such modeled IVHS results, is the availability of a benchmark which establishes their similarities and differences even before any IVHS elements are introduced.

This paper compares both models' traffic flow and traffic assignment fundamentals, in the absence of IVHS technologies, in order to establish a reference point from which any differences in IVHS features can be discussed. The results indicate that the two dynamic models provide very similar results for the same scenarios, but that subtle differences in their traffic flow and traffic assignment models can readily be discerned. It is recommended that other models, for evaluating the benefits of IVHS deployments, be examined and compared in a similar fashion before their results or features for larger networks are considered in detail.

1. INTRODUCTION

Dynamic traffic assignment/simulation models are playing an increasingly important role in the evaluation of alternative route guidance strategies, especially as a means of extrapolating the results of field experiments with a small number of test or prototype vehicles to much higher levels of potential market penetration. In North America, one of the more popular tools for performing such analyses has been the INTEGRATION model (1, 2), while in Europe the CONTRAM model (3), or derivations thereof, are being applied extensively (4).

The purpose of this paper is to explore some of the fundamental similarities and differences between these two models using the outputs of each model for four small sample network scenarios. The four sample scenarios deal with recurring congestion, non-recurring congestion, traffic signals and traffic assignment. While this analysis is far from exhaustive, it does sample four of the main traffic flow pillars upon which most more extensive network analyses of route guidance systems are based. The decision to consider these smaller networks was based on experience gained in earlier applications of both models. Specifically, even slightly larger networks were found to quickly mask many of the fundamental differences between the two models, as subtle model differences quickly began to interact and could therefore not be identified separately.

2. BACKGROUND

In order to focus on each model's fundamental traffic flow features the network, illustrated in Figure 1, was simulated using both models. In Scenarios 1 and 2 the network consisted of a six km section of road from A to B with a capacity of 2000 veh/hr, a free speed of 60 km/hr, a speed-at-capacity of 30 km/hr and a jam density of 100 veh/km. In Scenario 3, a 2 km long cross road with similar traffic flow characteristics was added from C to D. The speed-flow relationship for all links was set to approximate Greenshields' model, which is illustrated in Figure 2. It should also be noted that all analyses were performed for ten ten-minute time slices and that the vehicle packet size in CONTRAM was set to be one vehicle per packet. The latter provides for consistency with INTEGRATION's individual vehicle approach.

In the first recurring congestion example, a capacity bottleneck was introduced by means of assigning the 4th link in the network (link 13) a reduced capacity of only 1500 veh/hr for the entire analysis period and applying a temporal demand which briefly exceeded this reduced capacity. In the second non-recurring congestion example, the permanent capacity bottleneck was replaced a short term capacity blockage. For this scenario a constant traffic demand from A to B was applied. In the third example, a temporally varying traffic demand from C to D was introduced and a fixed time traffic signal was added at the intersection of the two roads. No further permanent or temporary blockages were considered.

Having illustrated independently the manner in which both models deal with recurring, non-recurring and traffic signal capacity on a fixed route network, the final example involves a scenario in which locations A and B are connected by means of 3 road segments of equal length which have the general characteristics of scenarios 1, 2 and 3, respectively. Route 1 has a permanent bottleneck placed on it, route 2 is made to experience an incident of finite duration, while route 3 has a traffic signal placed on it. The fourth example network therefore explores how both models dynamically assign traffic to these different alternate routes with previously established characteristics. The results for scenarios 1 to 3 are illustrated in Tables 1, 2 and 3, while the results for scenario 4 are illustrated in Figures 3a and b.

3. SCENARIO 1 : RECURRING CONGESTION

In Scenario 1 a demand of 1000 veh/hr is loaded onto the network for time slices 1 and 2, following which a demand of 1800 veh/hr is loaded for time slices 3 and 4. Subsequently, demands of 1500 veh/hr are loaded for time slices 5 to 8, and time slices 9 and 10 are concluded with a demand of 500 veh/hr.

It can be noted in both CONTRAM and INTEGRATION that, during time slice 1, the flows recorded on links 10 to 15 decrease from about 900 to 300 veh/hr, respectively. This phenomenon is due to the fact that it requires a finite amount of time for traffic flow to dynamically propagate across the network. As a result, a flow rate of 1000 veh/hr is only observed on the most downstream link for the last 2.5 to 3.5 minutes out of the first 10 minute time slice. This results in counts for link 15 ranging from 276 to 336 veh/hr, rather than being 1000 veh/hr. During the second time slice, the demand of 1000 veh/hr has propagated nearly entirely across the network, and some form of steady-state conditions exist in both dynamic models. The speeds in both models are very similar, especially given the fact that CONTRAM only approximated Greenshields' model in a piece wise fashion.

During time slices 3 and 4, one can observe the increased demand of 1800 veh/hr propagating across the network up to the bottleneck on link 13. The models provide very

similar results, except for the fact that CONTRAM constrains only the exit privileges of link 13, while INTEGRATION constrains both the exit and entry privileges of the bottleneck link. The effect of this difference is that, prior to any queue spill-back in CONTRAM, link 12 can discharge in excess of 1500 veh/hr (1770 veh/hr), while in INTEGRATION link 12 is constrained to 1500 veh/hr (1506 veh/hr). This effect is especially noticed in the queue listing at the end of each time slice, where CONTRAM estimates the presence of queues in the bottleneck (link 13), while INTEGRATION represents queues upstream of the bottleneck (link 12).

During time slices 5 to 8, when a demand of 1500 veh/hr is applied to the bottleneck with a capacity of 1500 veh/hr, steady-state queues are modeled in both models. However, INTEGRATION considers that, within the bottleneck link, vehicles are traveling at capacity (30 km/hr), while CONTRAM considers that travel on this link is queued (13 km/hr). The queue recovery during time slices 9 and 10 is very similar in both models.

4. SCENARIO 2: NON-RECURRING CONGESTION

Within Scenario 2 a constant demand of 1500 veh/hr is applied from time slice 1 to 8, while an incident on link 13 is considered to occur from time slice 3 to 6, which blocks half of the link's capacity. No demand is loaded during time slices 9 and 10 in order to clear the network of any vehicles. It can be noted that in both models, traffic flows and speeds reach and equilibrium in the second time slice at approximately 1500 veh/hr and that speeds are in the range of 40 to 48 km/hr. Once the incident occurs, the outflow from link 13 in both models drops to approximately 1000 veh/hr, and the speeds drop to about 8 to 10 km/hr.

A slight difference can be noted in the link queue comparisons, where CONTRAM considers the queue to have a density of 100 veh/km, while INTEGRATION considers the queues to only have a density of about 75 veh/km, even though both models were given a jam density of 100 veh/km. However, it is noteworthy that INTEGRATION considers that a jam density is not experienced until a queue is completely stationary (speed = 0 km/hr), such that a queued flow of 1000 veh/hr should have a density between the density-at-capacity and the jam density, as specified in Greenshields' model.

It is important to note, however, that while the models differ in terms of where they consider the queues to be located, the total queue size (summed over all links) in both scenarios is very similar in time slices 3 to 5. A difference does occur in time slice 6, where the queue spills back to the upstream start of the network. In this case, it appears that CONTRAM forces any departures to enter the initial link (creating a queue size of 126 vehicles), while INTEGRATION holds these vehicles in storage external to the network (hence preserving the target density on the link).

In time slice 7 it can again be noted that CONTRAM's fixed queue density results in instantaneous shockwaves, as soon as the incident is cleared, as the flow is nearly 2000 veh/hr on links 10 to 13. In contrast, INTEGRATION's modeling of the backward recovery wave results in flows approaching 2000 veh/hr at the cleared bottleneck, but lower flows further upstream. The model results in time slice 8 are very similar for both models, once CONTRAM's more condensed queues are accounted for. In time slice 10 both models consider a return to near free-speed conditions.

It is also interesting to note that CONTRAM considered queues to be present on links 14 and 15 during time slice 9. No clear explanation for the presence of these queues was found, but similar discrepancies have been found by others (5) who model the clearance of incidents macroscopically in a dynamic assignment model.

5. SCENARIO 3: SIGNAL IMPACTS

In scenario 3, a traffic signal with a 100 second cycle length and a 45 second effective green in each direction was coded to yield a net capacity of 900 veh/hr in each direction, given initial approach saturation flow rates of 2000 veh/hr. A traffic demand of 600 veh/hr was then loaded from A to B during time slices 1, 2, 7 and 8, while during time slices 3 to 6 a demand of 1200 veh/hr was loaded. Similarly, a demand of 600 veh/hr was loaded from C to D during time slices 1-4 and 7-8, while a demand of 1200 vehicles/hr was loaded during time slices 5 and 6.

The results from both models were found to be remarkably similar, except for the aforementioned differences in queue density. Specifically, when the flow was 600 veh/hr, no queues formed, while as soon as demands were 1200 veh/hr, both models considered the throughput to be limited to only 900 veh/hr. The resulting queues spilled back in each model to constrain upstream links in subsequent time slices. The only other small difference, that was observed, was during time slice 9 when CONTRAM considered the flows downstream of the intersection to exceed 900 veh/hr (1050 and 1074 veh/hr). This peculiar effect was thought to be similar in origin to the queues in time slice 9 for scenario 2.

6. SCENARIO 4: TRAFFIC ASSIGNMENT

Route guidance problems involve the solution to network analysis problems which involve sub-networks with characteristics such as those in scenario 1 to 3, and the traffic assignment of vehicles between them. Consequently, a network was coded for Scenario 4, as illustrated in Figure 1, which involves the dynamic assignment of traffic between 3 competitive routes, each with general features which were described earlier.

The demand loaded onto the network was held at a constant rate of 3000 veh/hr from time slice 1 to 8. Again, as in Scenarios 2 and 3 no demand was loaded during time slices 9 and 10. An incident (which blocked 0.75 lanes) was introduced on the second route (link 23) during time slices 3 to 6, while the signal timings on the third route (link 33) were set to a 25% effective green splits during time slices 1 to 4, and to a 75% effective green split during time slices 5 to 10. This resulted in an effective capacity on route 3 of 500 veh/hr and 1500 veh/hr, respectively. The first route had a permanent bottleneck placed on it (link 13) with a capacity of 1500 veh/hr.

It can be noted that at the entry of each route (Figure 3a), during time slices 1 and 2, both CONTRAM and INTEGRATION work towards an equilibrium traffic assignment in which most traffic uses routes 1 and 2, leaving only 500 out of 3000 veh/hr on signalized route 3. Once the incident has commenced (time slice 3) but before the signal timings on route 3 have been adjusted to accommodate any diversion (time slice 5), both models send most traffic down the first route. Unfortunately, during this time slice the “corridor capacity” is $1500 + 500 + 500 = 2500$ veh/hr, which is insufficient to service the total demand of 3000 veh/hr, regardless of which routing strategy is utilized. Differences between INTEGRATION and CONTRAM are therefore simply differences in terms of where each model elects to “park” the excess demand.

During time slices 5 and 6, increased green time is assigned to route 3, which allows it to triple its capacity. This results in INTEGRATION assigning it considerably more traffic during these same time slices. It is interesting to note, however, that CONTRAM has actually already anticipated this change in signal timings, and has already increased its loading of the signalized route during time slice 4. After the incident is cleared in time slice 7, both models gravitate towards a return to equilibrium conditions, and the resulting equal split in traffic loading. This equal split is in contrast to the unequal split in time

slice 2, where the lower route had a significantly lower capacity than the others, due to its much lower green split.

Figure 3b provides an interesting alternative perspective to this same problem, as it provides the flows at the down stream ends of each route. It can be noted that the flows during time slice 1 in both models are much lower than in Figure 3a, due to the time lag involved in traversing even an uncongested traffic network. Furthermore, it can be noted that the total flow arriving downstream of the network in time slices 3 to 4 is less than the total demand of 3000 veh/hr, for both models. This deficit is due to the storage of queues within the network. However, during time slices 6 and 7 in INTEGRATION and in time slices 5, 6 and 7 in CONTRAM, the arrivals exceed the inflows, as any stored en-route queues are cleared. CONTRAM is more effective at clearing these queues as it anticipates both the deployment of increased green time on route 3 and the removal of the incident on route 2.

It can also be noted in Figure 3b that INTEGRATION strictly adheres to the capacity restriction at 1500 veh/hr on route 1, and at 500 veh/hr during the incident on route 2 during time slices 3-6. The cause in CONTRAM of the variability of the flow on route 2 downstream of the incident during time slices 3 to 6 is not clear. However, it can be noted that during time slice 9, the flows in both models reflects the return to the equilibrium flows, which were observed at the route inflows in Figure 3a during time slice 8.

7. CONCLUSIONS AND RECOMMENDATIONS

It has been shown in the above examples that both INTEGRATION and CONTRAM have very similar dynamic traffic flow models for dealing with recurring and non-recurring congestion, as well as for dealing with traffic signals and traffic assignment. However, both models are also different in certain very specific ways that can be directly traced to their fundamental differences in modeling approaches. While each model has relative strengths and weaknesses, it is most important that any model, which is contemplated for use in the evaluation of IVHS strategies, be first examined in terms of how it behaves on various simple networks. Such tests will identify model features and characteristics which may either be masked in larger model deployments, or even be erroneously interpreted as being a result of a particular IVHS strategy.

It is recommended that the investigations of INTEGRATION and CONTRAM be further extended to analyze a wider range of conditions that each model may be expected to model, and that such investigations are subsequently extended to increasingly larger and more realistic networks. It is also recommended that those who are performing IVHS benefit studies with other combined traffic simulation/ assignment models, strive to present similar objective results on how their models performed on small test networks which are identical and/or similar to those presented in this paper. Such cross-model bench marking, while time consuming and sometimes humbling to model developers, is imperative in order to establish and maintain confidence in the validity and accuracy of the various models which are utilized in IVHS studies, benefit assessments and deployments.

REFERENCES

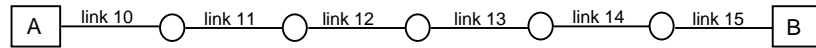
- [1] Van Aerde M. (1985), "Modeling of Traffic Flows, Assignment and Queuing in Integrated Freeway/Traffic Signal Networks," Ph.D. Thesis, Department of Civil Engineering, University of Waterloo, Canada.
- [2] Van Aerde M. and Yagar S. (1988), "Dynamic Integrated Freeway/Traffic Signal Networks: A Routeing-Based Modeling Approach," *Transportation Research*, 22A(6), pp. 445-453.

- [3] Transport and Road Research Laboratory (TRRL) (1989), "CONTRAM User Guide," Transport and Road Research Laboratory, Crowthorne, 1989.
- [4] Harris S.P., Rabone A.J., Randall D. and Stevens A. (1992), "ROGUS--A Simulation of Dynamic Route Guidance Systems," *Traffic Engineering and Control*, Vol. 33, May.
- [5] Yu L. (1994), "A Queuing-Based Dynamic Macroscopic Traffic Assignment/Simulation Model," Ph.D. Thesis, Department of Civil Engineering, Queen's University, Kingston, Canada.

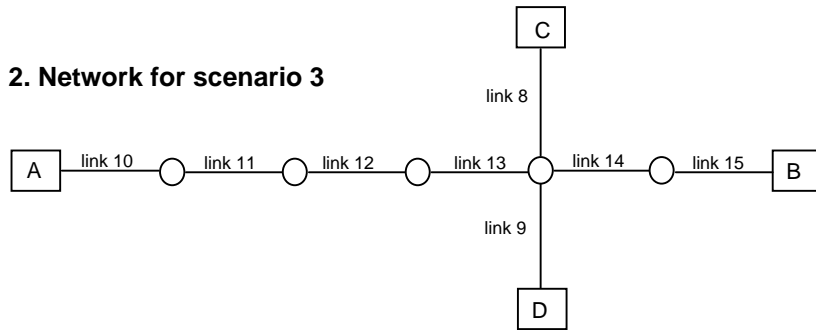
Table 3: Results of Scenario 3

CONTRAM link flows		Time S ice									
	1	2	3	4	5	6	7	8	9	10	
link 8	510	594	600	600	870	900	894	888	138	0	
link 9	444	600	600	600	810	924	948	834	240	0	
link 10	534	600	1116	1200	1200	1200	684	600	66	0	
link 11	468	600	1038	1200	1200	1200	762	600	132	0	
link 12	408	594	966	1194	1074	882	810	978	294	0	
link 13	330	582	822	894	900	900	900	894	894	0	
link 14	264	582	726	948	942	990	852	846	1050	0	
link 15	198	582	666	966	936	870	894	912	1074	0	
INTEGRATION link flows											
link 8	528	600	600	600	864	900	900	900	108	0	
link 9	432	600	600	600	810	900	900	900	258	0	
link 10	534	600	1116	1200	1200	1200	684	600	66	0	
link 11	468	600	1032	1200	1200	996	900	672	132	0	
link 12	402	600	948	1152	900	900	900	900	498	0	
link 13	282	600	720	900	900	900	900	900	900	0	
link 14	246	600	666	900	900	900	900	900	900	0	
link 15	186	600	624	900	900	900	900	900	900	0	
CONTRAM link speeds		Time S ice									
	1	2	3	4	5	6	7	8	9	10	
link 8	41	40	40	40	20	11	9	16	37	0	
link 9	56	55	55	55	54	52	52	54	58	0	
link 10	55	55	50	49	49	49	55	55	55	0	
link 11	56	55	50	49	49	49	54	55	58	0	
link 12	56	55	52	49	42	23	14	26	55	0	
link 13	44	39	29	16	10	8	8	7	9	0	
link 14	58	56	54	52	52	52	54	54	54	0	
link 15	58	56	55	52	52	52	54	54	52	0	
INTEGRATION link speeds											
link 8	42	42	42	42	17	9	9	25	59	0	
link 9	43	43	43	43	39	39	39	39	59	0	
link 10	53	53	47	47	47	47	53	53	59	0	
link 11	54	54	47	47	47	20	21	54	59	0	
link 12	54	54	47	39	14	9	9	9	59	0	
link 13	32	32	21	11	9	9	9	9	9	0	
link 14	44	44	43	43	43	43	43	43	43	0	
link 15	47	47	47	47	47	47	47	47	47	0	
CONTRAM link queues		Time S ice									
	1	2	3	4	5	6	7	8	9	10	
link 8	4	4	4	4	46	96	61	12	1	0	
link 9	0	0	0	0	0	0	0	0	0	0	
link 10	0	0	0	0	0	0	0	0	0	0	
link 11	0	0	0	0	0	0	0	0	0	0	
link 12	0	0	0	0	21	74	79	16	0	0	
link 13	2	4	14	62	98	99	108	99	15	0	
link 14	0	0	0	0	0	0	0	0	0	0	
link 15	0	0	0	0	0	0	0	0	0	0	
INTEGRATION link queues											
link 8	0	0	0	0	48	80	64	6	0	0	
link 9	0	0	0	0	0	0	0	0	0	0	
link 10	0	0	0	0	0	0	0	0	0	0	
link 11	0	0	0	0	0	27	12	0	0	0	
link 12	0	0	0	0	57	80	80	52	0	0	
link 13	0	0	23	80	80	80	80	80	32	0	
link 14	0	0	0	0	0	0	0	0	0	0	
link 15	0	0	0	0	0	0	0	0	0	0	

1. Network for scenarios 1 and 2



2. Network for scenario 3



3. Network for scenario 4

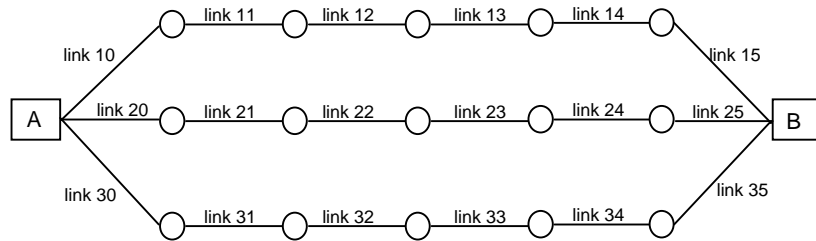


Figure 1: Network Configurations

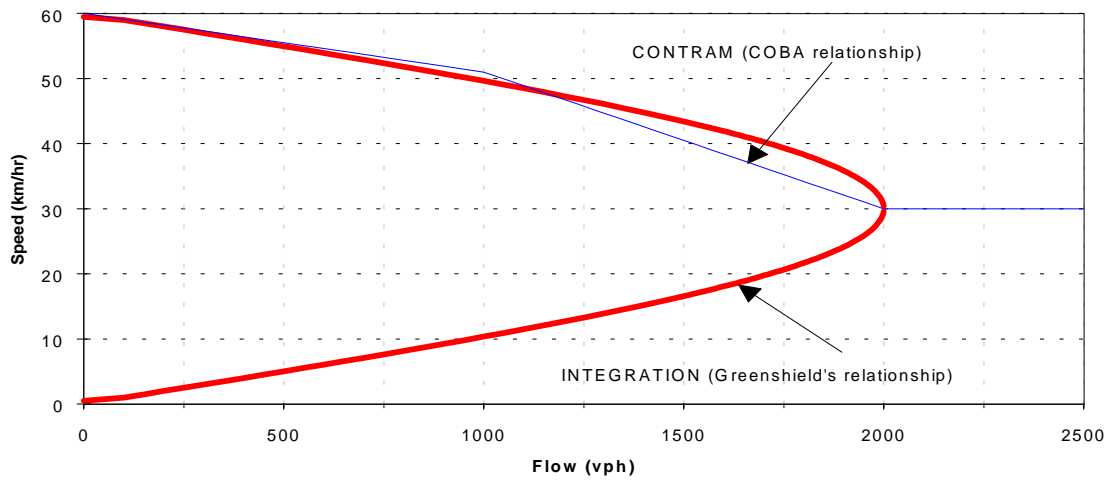


Figure 2: Speed-Flow relationships coded for the CONTRAM and INTEGRATION models

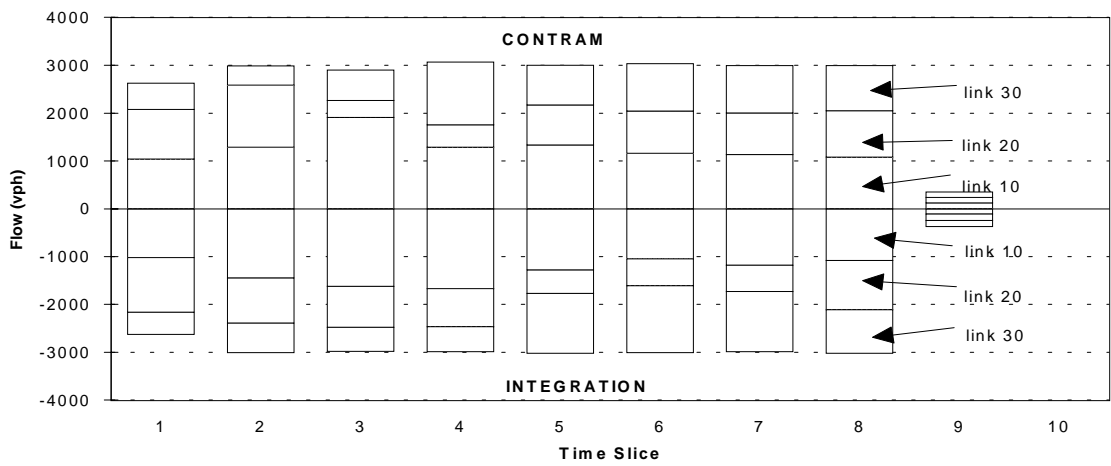


Figure 3a: Scenario 4 link flow comparison of entrance links

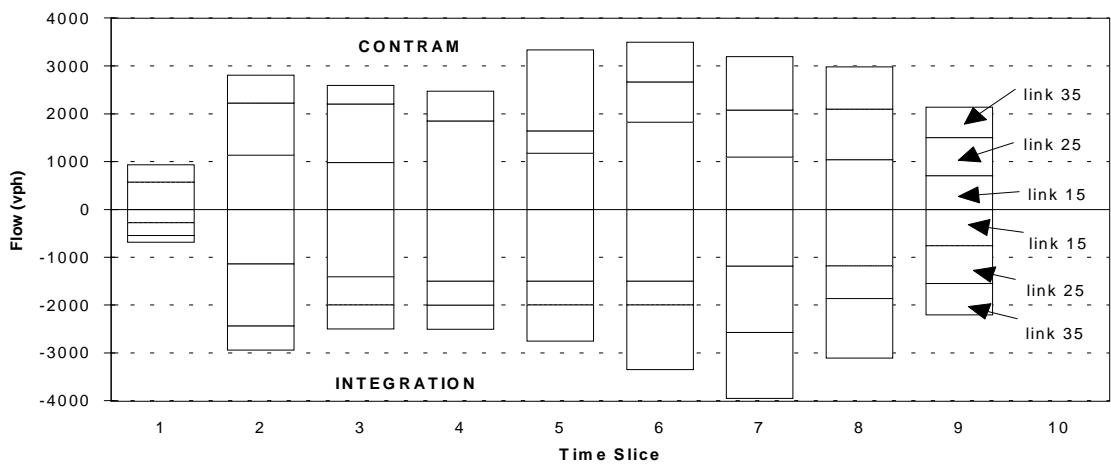


Figure 3b: Scenario 4 link flow comparison of exit links