1-1-2008

Regional Microscopic Simulation Model for Studying Traffic Control Strategies at Work Zone

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A report by the University of Vermont Transportation Research Center

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Report # 08-005

UVM TRC Report # 08-005

REGIONAL MICROSCOPIC SIMULATION MODEL FOR STUDYING TRAFFIC CONTROL STRATEGIES AT WORK ZONE

Final Report 2008

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1. INTRODUCTION

The Vermont Agency of Transportation (VTrans) undertook a major repaving/ reconstruction project over a six-mile segment of northbound lanes of Interstate 89 (I-89) in the summer of 2008. Given the critical role that I-89 plays in accommodating travel throughout Chittenden County and the State of Vermont, VTrans engineers were concerned with the impact that the project and the potential traffic control strategies would have on travel characteristics. VTrans proposed three traffic control strategies: 1) ST-1: no lane closure, but no shoulders in northbound direction, 2) ST-2: one northbound lane closure, and 3) ST-3: one northbound and one southbound lane closure (crossovers). The construction period was estimated to be two weeks for ST-2 and ST-3 and four weeks for ST-1. Obviously, the impact of a project of such magnitude on travel conditions is not likely to be limited to I-89 only, but would also affect the surrounding transportation network as drivers seek alternative routes.

In this study, VTrans contracted with the Transportation Research Center at UVM to use a UVM developed regional microscopic traffic simulation model to evaluate the impacts of the various work zone traffic control strategies.

Traffic control strategies ST-2 and ST-3 involved closing one lane in NB direction and ST-3 closed one SB lane. In the morning peak period, the northbound traffic is much higher on I-89. Thus the NB traffic is critical during morning period, especially for ST-2 and ST-3. A main observation of the morning peak analysis was that the construction activities divert traffic from I-89 to the alternative routes, primarily to US-2. During morning peak period, no significant reduction in speed is observed under any strategy, and the flow is observed to be moving smoothly. However, some increase in the density and reduction in speed were observed in the work zone.

During evening peak the southbound traffic is higher than the northbound traffic. However, the southbound flow was unaffected in ST-1 and ST-2. Thus, the impact of the project in ST-1 and ST-2 during evening peak was lesser than the morning peak period. Southbound lanes of I-89 carry higher traffic than northbound lanes during evening peak hours. However, the NB traffic is also affected due to the work zones, especially because all strategies involved a restriction on NB traffic. Similar to the morning peak analysis, the evening peak analysis revealed a fraction of the traffic seeking alternative routes. Because US-2 is a main alternative, the section of US-2 between VT-2A and VT-117, carried increased traffic. However, a small fraction of the traffic originally using US-2 was shifted to other routes. No severe traffic jam or serious speed reduction was observed under any strategy. Some reduction in speed and increased density in the work zone was observed.

Strategy ST-2 resulted in minimum construction cost and the traffic impact was expected to be comparable with the other strategies. Considering all options, VTrans officials selected ST-2 for implementation and requested UVM-TRC researcher to conduct further analysis for ST-2. Past experiences with traffic conditions in work zones in Vermont indicated that the free flow speed of 55 mph is very optimistic, especially considering the location of the project on a curve with an upward slope of about 5%. Therefore, three additional speed limits of 45, 35 and 25 mph were analyzed. Results showed that the reduced speed in work zone discouraged drivers from using I-89. The average percentage of NB traffic diversion during morning peak hours with the free flow speed of 25 mph was about 34%. However, the southbound traffic was largely unaffected. Estimated speed values indicated that the traffic would move without any significant queue formation. Akin to the morning peak, the result of the evening peak indicated that the percentage of traffic reduction increases with the decrease in the speed limit. Consequently, westbound traffic on US-2 increased as the speed limit in work zone was reduced.

The reconstruction work started on May 15, 2008 and the northbound lane was closed from Thursday May 15, 2008 to Sunday May 25, 2008. In order to analyze and compare the traffic characteristics during the construction period, VTrans collected traffic volume and speed at the work site both before and after construction. Traffic volume on I-89 at the work zone has two distinct peak periods and the volume during morning peak is higher than in the evening peak. During construction traffic volume was significantly less than the before construction traffic volume, especially during peak hours. The average reduction in volume during 7:00 to 9:00 AM was about 35%. The percentage of diversion estimated by the micro-simulation models was about 34% for a speed of 25 mph. Therefore at the reduced speed assumption the model predicted traffic diversion volume accurately. Unlike the weekday, hourly traffic on a weekend showed a single peak spread over several hours of a day. Additionally, there was no significant diversion of traffic from I-89 to other routes. In the absence of the work zone, on a weekday about 83% of vehicles moved at a speed between 61 to 75 mph. During the construction activities about 72% of the vehicles moved at a speed between 41 to 45 mph. The speed during construction was much higher than the speed anticipated by VTrans officials.

In this report we present traffic impact analysis of a work zone on interstate I-89 in Vermont modeled using a PARAMICS based micro-simulation model. Additionally, we analyze the traffic characteristics (traffic counts and speed) observed during-construction and compare it with the before-construction and model predicted traffic characteristics.

2. BACKGROUND

Developing an efficient traffic control strategy at work zones and their vicinity is a challenging task. The task is made more difficult when a work zone is on a major arterial requiring lane(s) closure. The potential negative impacts of traffic in work zones include increased accidents (Bryden, Andrew and Fortuniewicz 1998, Rouphall, Yang and Fazio 1988), reduced speed and capacity (Jiang, 1999; Al-Kaisy, Z and Hall 2000; Dixon, Hummer and Lorscheider 1996), and increased congestion and user costs (Jiang, 1999). The control strategies usually adopted by traffic managers at a work zone include using shoulders, partial road closing, one directional traffic flow, constructing crossovers, and closing the road in both directions. Usually the impact of work zones is not limited to the traffic on the road being repaired, but the work zone also affects the traffic on nearby roads. Thus control strategies at work zones may necessitate additional control strategies on nearby roads. The selection of any particular strategy is a tradeoff between construction work difficulty and traffic impact. For example, using only road shoulders and not closing any lane might have the least impact on traffic, but might increase construction cost by reducing contractor's staging areas. On the other hand, closing the entire road could make construction easier, but it could have significant impact on the traffic in terms of increased travel cost and discomfort/fatigue to travelers.

Ideally, the traffic manager should evaluate all feasible control strategies, taking into account both construction cost as well as users' discomfort and travel cost. The difficulty associated with evaluating control strategies, however, is that each work zone is unique. Work zones differ in terms of the number of lanes being closed, the length of the work zone, the duration of the work zone, allowable speed limits in and outside work zone, type of barricades in partial road closures, deployment of dynamic message signs (DMS) and other sign boards, road geometry at the work zone (gradient, curve, etc), type of the road, and the availability of the alternative routes. Although HCM2000 provides expressions for estimating capacity of freeway at work zones, it is not easy to develop standard analytical models to evaluate the overall performance of work zones. A microscopic simulation model is capable of modeling both traffic dynamics as well as travelers' complex routing logics (Zhang, 2004; Toledo and Koutsopoulos 2004; Mousa, Rouphal and Azadiva 1990; Smith, Sadek and Huang 2008); thus it is an appropriate tool for conducting work zone analysis. For work zones, the ability of the simulation model to capture drivers' routing behavior is critical, because drivers encountering a work zone are likely to seek alternative routes especially if appropriate information is provided via strategically-located DMS.

As discussed above, each work zone has unique characteristics, thus no standard analytical models to evaluate overall work zone impact are available in the literature. However, many empirical studies and experiences concerning the various aspects of work zones such as capacity, speed, user cost, and safety have been reported (Jiang, 1999). This study reported traffic flow reductions of up to about 21% traffic flow and up to about 56% in speed. Dixon, et al., (Dixon, Hummer and Lorscheider, 1996) determine work zone capacities for rural and urban freeways based on the traffic data from 24 work zones in North Carolina. The authors conclude that the intensity of work activity and the type of area (rural or urban) strongly affect work zone capacity.

Safety of workers and drivers in work zones is a primary concern, arguing for strong precautions to be taken while developing and implementing traffic control strategies. A study by Rouphall, et al. (Rouphall, Yang and Fazio 1988) documents the safety and operational aspects of 46 short term and long-term (construction lasted longer than 4 days) work zones in the Chicago metropolitan area. It is reported that long-term closures increased accidents by 88% during the existence of work zones.

An important observation from the literature review is that the majority of the past studies restrict the analysis to the work zone without giving much attention to the traffic and roads in the vicinity of the work zone. This is mainly because studying the impacts on the surrounding area would require modeling drivers' complex routing decisions including diversion to alternative routes. A static model such as user equilibrium traffic assignment cannot model work zones traffic dynamics realistically. Analytical approaches of modeling traffic dynamics suffer from many challenges such as simpler behavioral assumptions, complexity of analytical formulations, and other issues (Boyce, D and Ran 2001, Peeta and Ziliaskopoulos 2001). The difficulties with the analytical models have led researchers to develop simulation models to model traffic dynamics and drivers' behavior. Simulation models have become popular because of their ability to model various traffic flow conditions realistically therefore resulting in more accurate results (Ben-Akiva, et al. 1998, Peeta and Ziliaskopoulos 2001). For example, a large-scale micro-simulation model for the Salt Lake Area was developed by Rakha, et al., (1998) and a micro-simulation was used to model freeway work zone traffic control in Mousa, et al., (1990). Zhang, et al., (2004) present systematic validation of a microscopic simulation model that involves animation comparison and quantitative/statistical analysis at macroscopic and microscopic levels. Numerous other studies are found in the literature where microscopic simulation tools have been used to model traffic dynamics and drivers' behavior from relatively small highway facilities such as traffic signals to large-scale regions involving traffic and highways in multiple cities and towns.

The impact of the I-89 repaving project on travel conditions was not limited to I-89 only, but also the surrounding transportation network as drivers sought alternative routes. An analysis tool capable of evaluating the impact both on I-89 and the surrounding network and capable of capturing changes in travelers' routing behavior in response to the construction work was required. This was especially true, given that VTrans, as a part of the repaving project, intended to provide travelers' with real-time information on the expected delay through the work zone, using a series of strategically located DMS.

3. SCOPE AND OBJECTIVE OF THE PROJECT

VTrans requested the UVM research team to evaluate three traffic control strategies using microscopic traffic simulation to examine the effects on the morning and evening peak periods. The three strategies were as follows:

Strategy 1 (ST- 1): Under this strategy, two lanes would remain open in each direction (i.e. no lane closure was proposed) by opening the shoulder for traffic. The lanes, however, would be quite narrow, and traffic would move at a lower speed of 55 mph in the northbound direction of I-89. Traffic in the southbound direction would remain unaffected.

Strategy 2 (ST-2): This strategy includes closing one northbound lane, thus leaving one lane open for traffic. The southbound traffic is unaffected thus two lanes carry the traffic. Since the work zone does not affect the southbound traffic the speed limit is not changed. However, the speed limit of northbound traffic is changed to 55 mph.

Strategy 3 (ST-3): In this strategy, it is proposed to keep one lane open for traffic in each direction. This is achieved by closing both northbound lanes and using one southbound lane for the northbound traffic. Crossovers are proposed to be constructed to maneuver the traffic.

The estimated construction cost of each strategy was:

ST-1: $9,948,758.00

ST-2: $7,878,758.00

ST-3: $8,293,758.00

3.1 The Regional Microscopic Simulation Model

Many traffic simulation tools such as VISSIM (PTV-AG 2004) PARAMICS (Quadstone 2007), DYNASMART (Jayakrishnan, Mahmassani and Hu 1994), and MITSIM (Massachusetts Institute of Technology (MIT) 2000) have been developed in recent years to model traffic dynamics and drivers' behavior. In this study, a regional microscopic traffic simulation model previously developed by one of the authors was used to evaluate the likely impacts of the suggested work zone traffic control strategies and to make recommendations to VTrans aimed at minimizing the impact of the construction work on the transportation network performance.

The simulation model used in this study was developed for Chittenden County, an area of about 540 sq miles, and population of 146,000, using PARAMICS 6.2. The PARAMICS suite consists of three basic tools: 1) Modeller, the core network building tool, designed to operate at the microscopic level and integrates with the core PARAMICS tools, 2) Processor, a batch simulation management tool that reduces simulation run time, and 3) Analyser, a post simulation data analysis package.

The road network modeled included interstate, state highway, and other major routes. The trip matrices were obtained from the Chittenden County Metropolitan Planning Organization (CCMPO). The matrices were developed and calibrated for year 2000 and has a total of 367 traffic analysis zones (TAZs) including 17 external zones. The same zoning, used in the CCMPO model, is used in the micro-simulation model. More details of the model development and calibration are presented in Smith, Sadek and Huang (2008). Originally the model was developed only for the evening peak period. Therefore, in order to develop the demand profile during the morning peak, the authors used a diurnal trip distribution derived from a 24-hour trip diary survey conducted by the CCMPO in 1998. For the morning peak, the period modeled extended from 6:30 AM to 8:45 AM.

In order to validate the model, the traffic flow obtained from the model was compared with the field observed traffic counts—obtained from VTrans, at work zone and roads in its vicinity. Absolute percent difference between model and observed traffic ranged from 1% at some locations to 29% at others.

4. ANALYSIS

4.1 Model Validation

As discussed above the original PARAMICS model used year 2000 trip matrices and was developed only for the evening peak. For the purpose of this study, new trip tables were developed assuming 1% annual growth rate in trips since 2000. Thus there was a need to validate the updated model with the existing traffic condition to assess the model's accuracy. The scope of the validation effort was limited to the area near the proposed road improvement, thus the model is validated with the morning and evening traffic counts on the segment of I-89 to be repaved and the major arterials in its vicinity (US-2 and VT-2A). The traffic counter locations used in the study are shown in Figure 1.

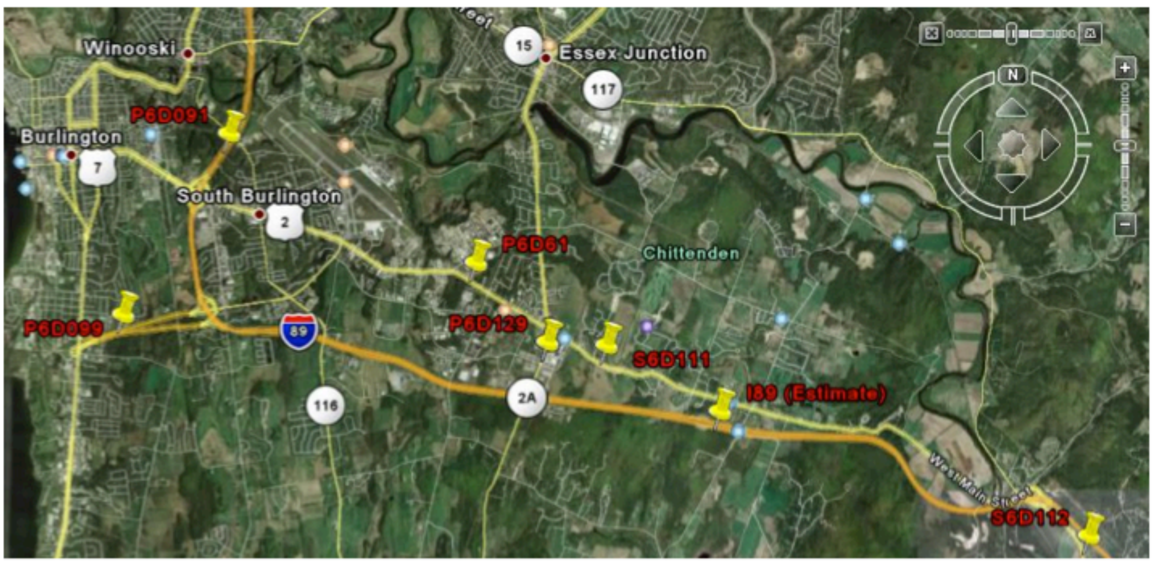

Figure 1 – Observed traffic count locations

Table 1 compares the simulated traffic counts to the field counts at seven locations in the vicinity of the proposed project for both the morning peak period (6:30 AM to 8:45 AM), and the evening peak period (3:30 PM to 5:45 PM). The initial 30 minutes were assumed to be the warm-up period, thus the simulated link counts during that period were not compared with the observed counts.

The observed traffic counts were not available for 15 minute intervals, thus simulation traffic counts for 8:45 AM to 9:00 AM and 5:45 PM to 6:00 PM were estimated by extrapolating the simulated traffic volume during the previous 45 minutes. In other words, the simulated traffic from 8:00 AM to 8:45 AM was assumed to be 75% of the traffic volume between 8:00AM to 9:00AM. Traffic between 5:00 PM to 6:00 PM was estimated similarly. With the exception of traffic counts on I-89, the observed traffic counts were not directional, thus the total volume is compared. The percentage difference with the observed volume is detailed in the last column indicating that the absolute percent difference ranges from 1% at some locations to 29% at others. For I-89, the two observed traffic counts indicate that the micro-simulation model underestimated the traffic on I-89 except for the traffic between 7:00 to 8:00 AM at P6D091. Route US-2 is an alternative route that runs parallel to I-89 along the construction zone. At one location on US-2, the model overestimated the traffic during both morning and evening peak periods. The trend at the other two locations varies from the morning to the evening peak. Given the stochastic nature of traffic, the authors felt that the micro-simulation model accuracy was adequate for the purposes of this project.

Table 1 - Comparison of Estimated Flows with Field Counts

Time		Simulation			Field observed	% difference
		NB	SB	Total		
		I-89 between exit 11 and 12				
7:00 AM	8:00 AM	1344	360	1704	2323	-26.6%
8:00 AM	9:00 AM	1593	527	2120	2150	-1.4%
4:00 PM	5:00 PM	924	1074	1998	2642	-24.4%
5:00 PM	6:00 PM	913	1095	2008	2760	-27.2%
		P6D129 (Williston VT2A just N of Marshall Ave)				
7:00 AM	8:00 AM	388	805	1193	1223	-2.5%
8:00 AM	9:00 AM	459	708	1167	1309	-10.9%
4:00 PM	5:00 PM	570	1035	1605	1792	-10.4%
5:00 PM	6:00 PM	592	1025	1617	1654	-2.2%
		P6D061 (Williston US2 0.2 mi E of industrial ave)				
7:00 AM	8:00 AM	475	379	854	663	28.9%
8:00 AM	9:00 AM	500	489	989	766	29.2%
4:00 PM	5:00 PM	617	613	1230	1163	5.8%
5:00 PM	6:00 PM	624	673	1297	1033	25.6%
		P6D099 (S Burlington I-189 0.4 mi E of US7)				
7:00 AM	8:00 AM	923	1395	2318	3198	-27.5%
8:00 AM	9:00 AM	1145	1711	2856	3201	-10.8%
4:00 PM	5:00 PM	2472	1611	4083	3833	6.5%
5:00 PM	6:00 PM	2528	1560	4088	4032	1.4%
		P6D091 (S Burlington I-89 0.7 mi N of US2 (Ext14))				
7:00 AM	8:00 AM	1995	1388	3383	3014	12.2%
8:00 AM	9:00 AM	2412	1600	4012	4238	-5.3%
4:00 PM	5:00 PM	2188	2550	4738	5507	-14.0%
5:00 PM	6:00 PM	1996	2905	4901	5312	-7.7%
		S6D111 (Williston US2 0.8 mi E of VT2A)				
7:00 AM	8:00 AM	548	87	635	825	-23.0%
8:00 AM	9:00 AM	664	103	767	782	-2.0%
4:00 PM	5:00 PM	183	1050	1233	1002	23.1%
5:00 PM	6:00 PM	189	1128	1317	1080	22.0%
		S6D112 (Richmond: US2 W of Village Cemetery Ent)				
7:00 AM	8:00 AM	673	96	769	764	0.6%
8:00 AM	9:00 AM	841	144	985	782	26.0%
4:00 PM	5:00 PM	271	530	801	826	-3.0%
5:00 PM	6:00 PM	279	557	836	1038	-19.4%

4.2 Evaluation of the three Traffic Control Strategies

The general trend of the traffic at the work zone was that the morning peak was more critical to northbound lanes since the residents of nearby towns (Williston, Jericho, Richmond, etc.) use the interstate for their morning commute north to Burlington. As a consequence, northbound lanes carry higher volumes during the morning peak (Table 1), which means that closing the northbound lane(s) will affect the morning peak traffic the most, and closing the southbound lane(s) closure will affect the evening peak traffic the most.

Figure 2 - Locations for comparing control strategies

The three control strategies were coded in the PARAMICS model individually and the model run for both morning and evening peak periods. In coding the different strategies, the following two assumptions were made: 1) the speed limit in work zone will be reduced from 65 MPH to 55 MPH, and 2) vehicles will be prohibited from passing in the work zone. An additional run of the base model without traffic control strategies was also conducted. The visual inspection during the simulation runs showed no indication of any serious traffic jam at any location in the vicinity of the project for any of the proposed control strategies. However, the model did indicate speed reduction and density increase in the work zone. Traffic diversion from I-89 to the alternative route US-2 was observed at Exit 11.

The outputs from the simulation runs of Modeller V6 were processed with Analyser V6 and reports were created to get information on traffic parameters (link counts, speed, delay etc). Three locations, shown in Figure 2, were selected at the work zone on I-89 and one on US-2 to compare the link count and speed under different control strategies. Location L-1 is in the work zone on I-89 at MM 80.00; location L-2 on US-2 where I-89 northbound diverting traffic can be captured; and location L-3 is on US-2 between northbound off-ramp and southbound off-ramp. Note L-3 does not capture traffic diverting from I-89 to US-2 at exit 11. The results at these locations are presented for morning peak and evening peak.

4.3 Morning Peak

Link counts and speed during morning peak on I-89 at the construction site (location L-1) for the northbound and southbound traffic are presented respectively in Table 2 and Table 3.

Table 2 - Comparison of northbound link flow and speed for three control strategies at L-1 (I-89 NB near MM 80.00)

Interval	Interval	Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	285	275	-3.5%	267	-6.3%	249	-12.6%	68.79	57.79	60.66	60.78
7:30	7:45	391	342	-12.5%	341	-12.8%	331	-15.3%	68.89	56.29	59.91	59.20
7:45	8:00	358	358	0.0%	340	-5.0%	356	-0.6%	69.45	56.57	59.33	59.55
8:00	8:15	409	393	-3.9%	397	-2.9%	388	-5.1%	68.63	56.12	59.48	59.28
8:15	8:30	393	408	3.8%	392	-0.3%	387	-1.5%	68.41	55.99	58.62	59.17
8:30	8:45	490	450	-8.2%	456	-6.9%	445	-9.2%	68.91	55.90	59.72	60.03
Total link counts (7:15 to 8:45)		2326	2226	-4.3%	2193	-5.7%	2156	-7.3%				
Average link flow (vehicles/hour)		1551	1484	-4.3%	1462	-5.7%	1437	-7.3%				

Table 3 - Comparison of southbound link flow and speed for three control strategies at L-1 (I-89 SB near MM 80.00)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	73	80	9.6%	88	20.5%	70	-4.1%	68.72	68.88	70.41	62.21
7:30	7:45	98	86	-12.2%	89	-9.2%	101	3.1%	69.26	70.31	71.24	61.32
7:45	8:00	108	114	5.6%	106	-1.9%	92	-14.8%	69.56	67.97	68.03	61.08
8:00	8:15	111	125	12.6%	115	3.6%	99	-10.8%	66.27	67.77	66.71	60.04
8:15	8:30	142	130	-8.5%	143	0.7%	148	4.2%	69.18	66.64	69.56	61.19
8:30	8:45	165	141	-14.5%	138	-16.4%	143	-13.3%	66.62	68.60	66.21	59.09
Total link counts (7:15 to 8:45)		697	676	-3.0%	679	-2.6%	653	-6.3%				
Average link flow (vehicles/hour)		465	451	-3.0%	453	-2.6%	435	-6.3%				

Since US-2 is an alternative route to I-89 in the area of the project, the reduction in the traffic on I-89 was expected to increase the traffic on US-2. This is clearly visible from the results of ST-2 and ST-3 in Table 4. I-89 N flow is parallel to US-2 West and I-89 S is parallel to US-2 East. ST-1 shows a small reduction in traffic, but this might be due to the randomness associated with PARAMICS model. The increase in traffic under strategies ST-2 is about 7% and ST-3 was about 12%, which can be attributed to the diverted traffic from I-89. Table 5 indicates there is slight reduction in eastbound (EB) traffic on US-2. The reduction is not very significant, thus not conclusive to relate to the project impact. One probable reason, in addition to the model randomness, is that a fraction of the traffic, which uses a part of the US-2 E and takes the on ramp at exit 11, is taking routes other than I-89 and US-2. Similar reasoning can also be given to the results in Table 6. Note that the location L-3 excludes the traffic diverting from I-89 to US-2 at exit 11.

Table 4 - Comparison of northbound link flow and speed for three control strategies at L-2 (US-2 WB)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	45	51	13.3%	51	13.3%	73	62.2%	42.74	42.25	43.09	43.03
7:30	7:45	46	52	13.0%	60	30.4%	64	39.1%	41.64	41.72	41.57	41.67
7:45	8:00	68	69	1.5%	92	35.3%	72	5.9%	41.91	42.57	41.96	42.40
8:00	8:15	76	78	2.6%	69	-9.2%	83	9.2%	42.66	41.79	42.08	41.79
8:15	8:30	136	100	-26.5%	112	-17.6%	100	-26.5%	41.53	42.64	42.87	42.62
8:30	8:45	48	63	31.3%	64	33.3%	76	58.3%	41.38	42.40	41.67	41.34
Total link counts (7:15 to 8:45)		419	413	-1.4%	448	6.9%	468	11.7%				
Average link flow (vehicles/hour)		279	275	-1.4%	299	6.9%	312	11.7%				

Table 5 - Comparison of southbound link flow and speed for three control strategies at L-2 (US-2 EB)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	59	53	-10.2%	49	-16.9%	58	-1.7%	38.95	38.77	38.76	38.86
7:30	7:45	60	67	11.7%	60	0.0%	67	11.7%	37.83	38.44	38.41	38.72
7:45	8:00	78	76	-2.6%	77	-1.3%	66	-15.4%	38.82	39.02	38.87	39.30
8:00	8:15	79	84	6.3%	84	6.3%	93	17.7%	38.40	38.32	39.06	38.78
8:15	8:30	93	88	-5.4%	85	-8.6%	81	-12.9%	38.55	38.88	38.72	38.66
8:30	8:45	124	108	-12.9%	118	-4.8%	116	-6.5%	37.32	37.41	37.73	38.19
Total link counts (7:15 to 8:45)		493	476	-3.4%	473	-4.1%	481	-2.4%				
Average link flow (vehicles/hour)		329	317	-3.4%	315	-4.1%	321	-2.4%				

Table 6 - Comparison of northbound link flow and speed for three control strategies at L-3 (US-2 WB between I-89 NB and SB ramps at exit 11)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	127	128	0.8%	128	0.8%	128	0.8%	45.38	45.53	45.49	45.01
7:30	7:45	181	185	2.2%	171	-5.5%	178	-1.7%	45.10	44.88	45.16	44.93
7:45	8:00	186	181	-2.7%	187	0.5%	180	-3.2%	44.06	44.42	44.64	44.77
8:00	8:15	207	199	-3.9%	198	-4.3%	203	-1.9%	45.80	45.96	45.37	45.61
8:15	8:30	207	210	1.4%	207	0.0%	202	-2.4%	45.21	44.96	45.49	45.10
8:30	8:45	220	211	-4.1%	213	-3.2%	214	-2.7%	44.95	45.11	45.64	45.14
Total link counts (7:15 to 8:45)		1128	1114	-1.2%	1104	-2.1%	1105	-2.0%				
Average link flow (vehicles/hour)		752	743	-1.2%	736	-2.1%	737	-2.0%				

Table 7 - Comparison of southbound link flow and speed for three control strategies at L-3 (US-2 EB between I-89 NB and SB ramps at exit 11)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
7:15	7:30	127	128	0.8%	128	0.8%	128	0.8%	45.38	45.53	45.49	45.01
7:30	7:45	181	185	2.2%	171	-5.5%	178	-1.7%	45.10	44.88	45.16	44.93
7:45	8:00	186	181	-2.7%	187	0.5%	180	-3.2%	44.06	44.42	44.64	44.77
8:00	8:15	207	199	-3.9%	198	-4.3%	203	-1.9%	45.80	45.96	45.37	45.61
8:15	8:30	207	210	1.4%	207	0.0%	202	-2.4%	45.21	44.96	45.49	45.10
8:30	8:45	220	211	-4.1%	213	-3.2%	214	-2.7%	44.95	45.11	45.64	45.14
Total link counts (7:15 to 8:45)		1128	1114	-1.2%	1104	-2.1%	1105	-2.0%				
Average link flow (vehicles/hour)		752	743	-1.2%	736	-2.1%	737	-2.0%				

ST-2 and ST-3 involved closing one lane in NB direction, but only ST-3 needs closing one SB lane. In the morning peak period, the northbound traffic is much higher on I-89. Thus the NB traffic is critical during morning period, especially for ST-2 and ST-3. A main observation of the morning peak analysis is that the construction activities divert traffic from I-89 to the alternative route US-2. No significant reduction in speed is observed under any strategy, and the flow is observed to be moving slowly. However, some increase in the density and reduction in speed are observed in the work zone. The analysis of evening peak is presented next.

4.4 Evening Peak

The evening peak model was run for the period of 3:30 PM to 5:45. Similar to the morning peak analysis, initial 45 minutes were assumed to be a warm up period and the results during 4:15 through 5:45 PM are presented below. During evening peak the southbound traffic was higher than the northbound traffic. However, the southbound flow is unaffected in

ST-1 and ST-2. Thus, the impact of the project in ST-1 and ST-2 during evening peak is expected to be lesser than during morning peak period. The evening peak period traffic in the SB direction is lesser than the morning peak NB traffic. The project site is closer to exit 11 than exit 12, thus SB lanes can accommodate much longer queues than the NB lanes, without obstructing traffic on other streets.

Link counts and speed values at three locations for the base case and three control strategies are presented in Table 8 through Table 13. The same locations as in morning peak are selected to compare the results in evening peak. Table 8 shows that some traffic from I-89 is diverted to other routes, but the percentage of diverted traffic is lesser than that during morning peak. A minimal SB traffic diversion is observed in ST-1 and ST-2, since no lane is closed. But the diversion in ST-3 is about 12% because one SB lane is closed.

Table 8 - Comparison of northbound link flow and speed for three control strategies at L-1 (I-89 NB near MM 80.00)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base cas	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	239	228	-4.6%	226	-5.4%	212	-11.3%	68.53	56.72	60.85	60.69
16:30	16:45	224	239	6.7%	241	7.6%	213	-4.9%	67.91	57.25	59.40	61.41
16:45	17:00	229	226	-1.3%	229	0.0%	221	-3.5%	70.23	56.96	61.04	61.31
17:00	17:15	232	250	7.8%	228	-1.7%	225	-3.0%	70.06	56.64	61.95	60.97
17:15	17:30	274	238	-13.1%	252	-8.0%	245	-10.6%	70.83	57.09	60.72	61.33
17:30	17:45	188	163	-13.3%	192	2.1%	202	7.4%	69.10	57.68	60.81	61.04
Total link counts (16:15 to 17:45)		1386	1344	-3.0%	1368	-1.3%	1318	-4.9%				
Average link flow (vehicles/hour)		924	896	-3.0%	912	-1.3%	879	-4.9%				

Table 9 - Comparison of southbound link flow and speed for three control strategies at L-1 (I-89 SB near MM 80.00)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	295	267	-9.5%	247	-16.3%	282	-4.4%	67.97	67.68	68.38	59.00
16:30	16:45	216	258	19.4%	265	22.7%	220	1.9%	70.16	70.84	68.66	60.57
16:45	17:00	298	320	7.4%	324	8.7%	270	-9.4%	67.92	66.61	67.31	58.34
17:00	17:15	245	229	-6.5%	221	-9.8%	276	12.7%	68.45	68.55	67.89	58.09
17:15	17:30	304	327	7.6%	282	-7.2%	193	-36.5%	68.11	67.20	68.84	59.77
17:30	17:45	267	216	-19.1%	237	-11.2%	187	-30.0%	68.04	39.85	68.43	60.47
Total link counts (16:15 to 17:45)		1625	1617	-0.5%	1576	-3.0%	1428	-12.1%				
Average link flow (vehicles/hour)		1083	1078	-0.5%	1051	-3.0%	952	-12.1%				

Similar to the morning peak results, the evening peak traffic on US-2 at location L-2 is increased, but as expected the amount of increase is smaller (see Table 10. A small percentage of reduction in EB traffic on US-2 is observed in ST-1 and ST-2. But the ST-3 results in slightly higher traffic, which can be attributed to the lane closure on I-89 S. A possible reason for the reduction in ST-1 and ST-2, in addition to the model randomness, is that a part of the traffic that takes US-2 East and takes on ramp at exit 11 to travel I-89 N is diverting to other alternatives. A higher reduction in ST-2 is also logical since ST-2 includes one lane closure.

Table 10 - Comparison of westbound link flow and speed for three control strategies at L-2 (US-2 WB)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	200	209	4.5%	187	-6.5%	210	5.0%	38.92	38.51	39.31	38.92
16:30	16:45	199	200	0.5%	204	2.5%	211	6.0%	39.49	39.68	39.39	39.35
16:45	17:00	225	218	-3.1%	211	-6.2%	230	2.2%	38.47	38.49	38.62	38.22
17:00	17:15	215	188	-12.6%	212	-1.4%	227	5.6%	39.00	39.41	38.88	35.63
17:15	17:30	238	241	1.3%	245	2.9%	223	-6.3%	36.96	38.64	38.41	39.22
17:30	17:45	233	243	4.3%	196	-15.9%	240	3.0%	37.32	35.33	39.16	36.11
Total link counts (16:15 to 17:45)		1310	1299	-0.8%	1255	-4.2%	1341	2.4%				
Average link flow (vehicles/hour)		873	866	-0.8%	836.7	-4.2%	894	2.4%				

Table 11 - Comparison of eastbound link flow and speed for three control strategies at L-2 (US-2 EB)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	33	41	24.2%	52	57.6%	58	75.8%	35.90	38.82	39.90	39.37
16:30	16:45	49	50	2.0%	48	-2.0%	69	40.8%	38.53	38.14	39.97	40.94
16:45	17:00	75	65	-13.3%	68	-9.3%	70	-6.7%	38.97	36.20	37.93	34.88
17:00	17:15	68	56	-17.6%	60	-11.8%	60	-11.8%	37.60	39.45	38.20	36.24
17:15	17:30	50	68	36.0%	48	-4.0%	53	6.0%	36.98	38.10	38.22	37.42
17:30	17:45	54	66	22.2%	54	0.0%	49	-9.3%	37.58	38.44	35.56	36.89
Total link counts (16:15 to 17:45)		329	346	5.2%	330	0.3%	359	9.1%				
Average link flow (vehicles/hour)		219	230.67	5.2%	220	0.3%	239	9.1%				

Link counts and speed between I-89 NB and SB ramps on US-2 (location L-3) is given in Table 12 and Table 13. Note that the WB traffic at location L-3 does not include the NB traffic diverted at exit 11 to take US-2 West. The results in Table 12 indicate that the traffic that was taking US-2 West is diverting to alternative routes because of the project. This same reason can be applied to the reduction in EB traffic in ST-1 and ST-2 (Table 13). As seen in Table 9, about 12 percent traffic is diverted to alternative routes in ST-3. Thus, the increase in traffic at L-3 in ST-3 can be attributed to the diversion of I-89 S traffic due to lane closure.

Table 12 - Comparison of westbound link flow and speed for three control strategies at L-3 (US-2 WB between I-89 NB and SB ramps at exit 11)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	51	52	2.0%	59	15.7%	55	7.8%	41.81	42.33	41.09	42.11
16:30	16:45	79	86	8.9%	71	-10.1%	72	-8.9%	42.23	41.55	42.92	42.14
16:45	17:00	54	67	24.1%	61	13.0%	62	14.8%	43.35	41.31	41.91	42.60
17:00	17:15	85	79	-7.1%	78	-8.2%	71	-16.5%	42.45	42.28	43.04	43.72
17:15	17:30	60	47	-21.7%	52	-13.3%	55	-8.3%	43.42	44.72	43.72	43.18
17:30	17:45	54	44	-18.5%	53	-1.9%	33	-38.9%	41.62	41.10	42.33	46.52
Total link counts (16:15 to 17:45)		383	375	-2.1%	374	-2.3%	348	-9.1%				
Average link flow (vehicles/hour)		255	250	-2.1%	249	-2.3%	232	-9.1%				

Table 13 - Comparison of eastbound link flow and speed for three control strategies at L-3 (US-2 EB between I-89 NB and SB ramps at exit 11)

Start Interval	End Interval	Link Count							Link Speed (mph)			
		Base case	ST-1		ST-2		ST-3		Base	ST-1	ST-2	ST-3
16:15	16:30	300	303	1.0%	292	-2.7%	306	2.0%	27.12	32.28	24.80	21.64
16:30	16:45	287	306	6.6%	298	3.8%	316	10.1%	34.50	30.79	35.22	26.61
16:45	17:00	318	304	-4.4%	297	-6.6%	324	1.9%	30.38	29.29	29.66	26.60
17:00	17:15	320	283	-11.6%	307	-4.1%	332	3.8%	29.51	32.72	20.54	21.75
17:15	17:30	330	324	-1.8%	332	0.6%	333	0.9%	24.94	21.68	19.93	20.45
17:30	17:45	316	318	0.6%	289	-8.5%	333	5.4%	26.03	14.72	21.48	19.86
Total link counts (16:15 to 17:45)		1871	1838	-1.8%	1815	-3.0%	1944	3.9%				
Average link flow (vehicles/hour)		1247	1225	-1.8%	1210	-3.0%	1296	3.9%				

Southbound lanes of I-89 carry higher traffic than northbound lanes during evening peak hours. However, the NB traffic is also affected due to the work zones, especially because all the strategies involve restriction on NB traffic. The analysis reveals a fraction of the traffic seek alternative routes, thus reduction in I-89 traffic (similar to the morning peak analysis). US-2 being a main alternative, the section of US-2 between VT-2A and VT-117, carries increased traffic. However, a small fraction of the traffic originally using US-2 is shifted to other routes. Again no severe traffic jam or serious speed reduction is observed under any strategy. Some reduction in speed and increased density in the work zone is observed.

As discussed above the selection of control strategy is the tradeoff between construction cost and traffic impact cost. ST-2 resulted in minimum construction cost strategy. Since the construction period under ST-2 and ST-3 is similar, the ST-3 results in higher traffic impact. Thus ST-2 is preferred to ST-3 under given circumstances. If the construction periods of ST-1 and ST-2 were the same, then ST-1 is expected to affect the traffic least. However, ST-1 is expected to require 30 days, thus the comparison of ST-1 and ST-2 would ideally require finding user cost under ST-1 and ST-2. Such analysis is beyond the scope of this study. Based on the experience and judgment of VTrans officials, ST-2 is selected for implementation. Thus VTrans requested UVM-TRC researcher to conduct further analysis for ST-2.

5. SPEED SCENARIOS FOR STRATEGY ST-2

The results in the previous section conclude ST-2 is not expected to severely impact traffic in the project impact area, if the free flow speed is 55 mph. However, the past experience on traffic condition in work zones in Vermont indicates that the free flow speed of 55 mph is very optimistic. Additionally, the location of the project is on a hill with 5% upward slope for the northbound traffic. A further complication is that the work zone is on a long curve. Three additional speed scenarios were developed for ST-2. The outputs of the ST-2 simulation model are analyzed for the speed of 45, 35 and 25 mph. The model is run for both morning and evening peak periods. A screen shot of the model near exit 11 at about 7:45 AM with speed limit of 25 mph is shown in Figure 3.

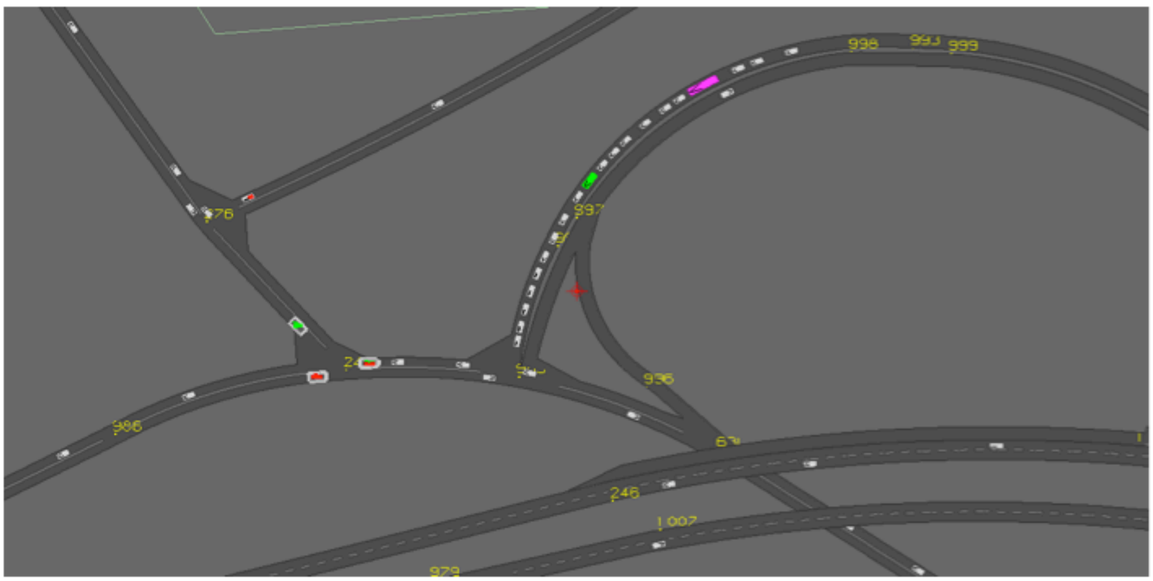

Figure 3 - A screenshot of PARAMICS micro-simulation at about 7:45 AM (SP-III, 25 mph)

In this section results of the three speed scenarios under ST-2 and the base case are compared and analyzed. The same three locations, used to compare result of different control strategies, are selected. Link flow and link speed values for morning peak are presented in Table 14 through Table 17. Note the link flow values in all tables for each 15 min period are in vehicles per hour, obtained by multiplying with 4 to the actual link count during each 15 min period.

The results in Table 14 show that the reduced speed in work zone discourages drivers from using I-89. The average percentage of NB traffic diversion during morning peak hours with the free flow speed of 25 mph is about 34%. The speed values indicate that the traffic would move without any significant queue formation. It can be observed from Table 15 that the southbound traffic is unaffected. This is because no lane is closed and no speed restrictions are implemented on southbound traffic in ST-2. As a consequence no eastbound traffic data is analyzed at locations L-2 and L-3 on US-2.

Table 14 - Comparison of northbound link flow and speed for at L-1 (I-89 NB near MM 80.00)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
7:15	7:30	1176	972	-17.3%	884	-24.8%	648	-44.9%	70.83	49.72	39.00	27.76
7:30	7:45	1344	1264	-6.0%	976	-27.4%	804	-40.2%	69.46	48.97	38.18	27.40
7:45	8:00	1496	1188	-20.6%	1268	-15.2%	968	-35.3%	68.35	48.71	37.64	27.43
8:00	8:15	1672	1568	-6.2%	1260	-24.6%	1040	-37.8%	68.51	48.80	38.02	26.97
8:15	8:30	1504	1168	-22.3%	1124	-25.3%	1144	-23.9%	68.97	50.07	38.36	27.00
8:30	8:45	1712	1680	-1.9%	1364	-20.3%	1300	-24.1%	67.92	48.08	37.52	26.74
Total link counts (7:15 to 8:45)		2226	1960	-11.9%	1719	-22.8%	1476	-33.7%				
Average link flow (vehicles/hour)		1484	1306.7	-11.9%	1146	-22.8%	984	-33.7%				
		Note: The f low is per hour and not per 15 minutes										

Table 15 - Comparison of southbound link flow and speed at L-1 (I-89 SB near MM 80.00)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base ca	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
7:15	7:30	296	328	10.8%	300	1.4%	332	12.2%	69.92	72.28	69.88	70.43
7:30	7:45	360	344	-4.4%	376	4.4%	396	10.0%	72.41	69.91	70.70	71.03
7:45	8:00	464	472	1.7%	424	-8.6%	404	-12.9%	69.39	68.98	70.69	69.64
8:00	8:15	400	368	-8.0%	416	4.0%	396	-1.0%	69.53	70.33	68.85	70.23
8:15	8:30	524	572	9.2%	564	7.6%	584	11.5%	67.16	67.28	65.47	66.43
8:30	8:45	616	540	-12.3%	564	-8.4%	548	-11.0%	65.70	67.76	68.21	68.19
Total link counts (7:15 to 8:45)		665	656	-1.4%	661	-0.6%	665	0.0%				
Average link flow (vehicles/hour)		443.33	437.33	-1.4%	440.67	-0.6%	443.33	0.0%				
		Note: The f low is per hour and not per 15 minutes										

The large percentage of diversion from I-89 results in a significant increase in the volume on US-2 (Table 16). When the speed in work zone is 45 mph the increase in peak hour traffic is about 26% and when the speed is reduced to 25 mph, the increase in traffic is about 76%. Nevertheless, it appears that even with these more conservative estimates for traffic speed (e.g. 25 mph) in the work zone, the network performance would still be acceptable, although a significant percentage of drivers would have to divert to US-2 to maintain acceptable flow conditions. There is a decrease in the traffic flow at location L-3 and the traffic flow decreases with the decrease in the speed on I-89. This indicates a fraction of the traffic originally using US-2 is diverted to alternative routes.

Table 16 - Comparison of westbound link flow and speed at L-2 (US-2 WB)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base ca	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
7:15	7:30	204	272	33.3%	400	96.1%	472	131.4%	43.26	41.51	43.08	43.24
7:30	7:45	216	296	37.0%	384	77.8%	592	174.1%	42.62	42.82	42.57	43.22
7:45	8:00	284	376	32.4%	304	7.0%	476	67.6%	42.92	42.06	42.51	42.72
8:00	8:15	328	448	36.6%	604	84.1%	700	113.4%	42.26	42.26	42.68	41.99
8:15	8:30	516	620	20.2%	656	27.1%	540	4.7%	41.38	42.84	42.15	42.38
8:30	8:45	396	436	10.1%	652	64.6%	644	62.6%	43.09	41.87	41.83	41.84
Total link counts (7:15 to 8:45 AM)		486	612	25.9%	750	54.3%	856	76.1%				
Average link flow (vehicles/hour)		324.00	408.00	25.9%	500.00	54.3%	570.67	76.1%				
		Note: The f low is per hour and not per 15 minutes										

Table 17 - Comparison of westbound link flow and speed for three control strategies at L-3 (US-2 WB between I-89 NB and SB ramps at exit 11)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base case	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
7:15	7:30	172	168	-2.3%	192	11.6%	152	-11.6%	39.52	39.52	38.85	39.54
7:30	7:45	228	256	12.3%	228	0.0%	224	-1.8%	38.56	38.95	38.52	38.76
7:45	8:00	252	260	3.2%	300	19.0%	268	6.3%	39.21	38.59	39.21	39.33
8:00	8:15	316	352	11.4%	248	-21.5%	256	-19.0%	38.49	38.85	39.13	39.33
8:15	8:30	300	320	6.7%	344	14.7%	328	9.3%	38.48	38.65	38.70	38.67
8:30	8:45	364	404	11.0%	336	-7.7%	328	-9.9%	38.95	39.36	39.14	38.21
Total link counts (7:15 to 8:45		408	440	7.8%	412	1.0%	389	-4.7%				
Average link flow (vehicles/hour)		272.00	293.33	7.8%	274.67	1.0%	259.33	-4.7%				
		Note: The f low is per hour and not per 15 minutes										

5.1 Evening Peak

As discussed above SB traffic is higher than NB during evening peak hours. Additionally, NB evening peak traffic volume is less than the morning peak NB traffic. Thus, the overall impact of evening peak traffic is expected to be less than the morning peak traffic. Table 18 shows the percentage of traffic reduction increases with the decrease in the speed limit. Consequently, westbound traffic on US-2 increases as the speed limit in work zone is reduced (Table 19).

Table 18 - Comparison of northbound link flow and speed at L-1 (I-89 NB near MM 80.00)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base case	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
16:15	16:30	928	788	-15.1%	728	-21.6%	636	-31.5%	69.41	50.36	39.21	27.92
16:30	16:45	888	840	-5.4%	720	-18.9%	572	-35.6%	69.92	49.64	38.67	28.12
16:45	17:00	928	816	-12.1%	796	-14.2%	624	-32.8%	69.39	49.40	38.94	27.61
17:00	17:15	888	780	-12.2%	696	-21.6%	656	-26.1%	71.01	50.62	39.19	28.18
17:15	17:30	972	960	-1.2%	824	-15.2%	700	-28.0%	69.49	49.62	38.68	27.53
17:30	17:45	788	736	-6.6%	696	-11.7%	620	-21.3%	68.10	50.28	38.83	28.02
Total link counts (16:15 to 17:45)		1348	1230	-8.8%	1115	-17.3%	952	-29.4%				
Average link flow (vehicles/hour)		898.67	820.00	-8.8%	743.33	-17.3%	634.67	-29.4%				
		Note: The f low is per hour and not per 15 minutes										

Table 19 - Comparison of westbound link flow and speed at L-2 (US-2 WB)

Start Interval	End Interval	Link Flow (vehicles/hour)							Link Speed (mph)			
		Base case	SP-I (45 mph)		SP-II (35 mph)		SP-III (25 mph)		Base	SP-I	SP-II	SP-III
16:15	16:30	216	288	33.3%	348	61.1%	384	77.8%	38.95	37.97	39.15	40.88
16:30	16:45	180	228	26.7%	288	60.0%	368	104.4%	39.55	38.00	39.75	40.18
16:45	17:00	292	328	12.3%	336	15.1%	500	71.2%	35.01	36.82	36.38	38.13
17:00	17:15	264	364	37.9%	424	60.6%	464	75.8%	36.88	37.64	38.89	37.51
17:15	17:30	260	256	-1.5%	308	18.5%	348	33.8%	38.56	38.84	37.18	37.13
17:30	17:45	220	244	10.9%	248	12.7%	376	70.9%	40.21	34.21	38.06	32.82
Total link counts (16:15 to 17:45)		358	427	19.3%	488	36.3%	610	70.4%				
Average link flow (vehicles/hour)		238.67	284.67	19.3%	325.33	36.3%	406.67	70.4%				
		Note: The f low is per hour and not per 15 minutes										

6. FIELD OBSERVED TRAFFIC DATA DURING CONSTRUCTION

The reconstruction work started on May 15, 2008 and the northbound lane was closed from Thursday May 15, 2008 to Sunday May 25, 2008. In order to analyze and compare the traffic characteristics during the construction period, VTrans collected traffic volume and speed at the work site both before and after construction. Before construction hourly traffic volumes were collected on northbound lanes starting from 1:00 PM on Tuesday May 06, 2008 to Monday, May 12, 2008. The during construction traffic data collection started on 11:00 AM on Thursday May 15, 2008 and ended 10 AM on Tuesday May 20, 2008.

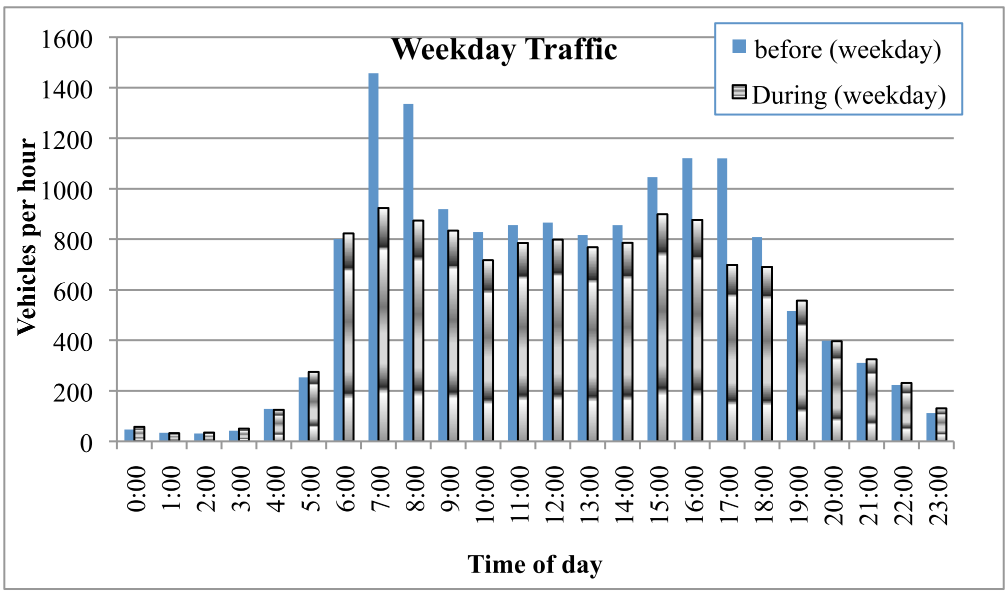

Figure 4 - Comparison of before and after traffic volumes on weekdays

Figure 4 compares traffic volumes on I-89 at the work zone before and after the beginning of construction. As can be seen, traffic volume on I-89 at the work zone has two distinct peak periods and the volume during morning peak is higher than in the evening peak. The plot shows that during construction traffic volume is significantly less than the before construction traffic volume, especially during peak hours. The average reduction in volume during 7:00 to 9:00 AM is about 35%. The percentage of diversion estimated by the micro-simulation models was about 34% for the speed of 25 mph. Therefore at the reduced speed assumption the model predicted traffic diversion volume accurately. Unlike the weekday the hourly traffic on a weekend shows a single peak spread over several hours of a day (Figure 5). Additionally, there is no significant diversion of traffic from I-89 to other routes.

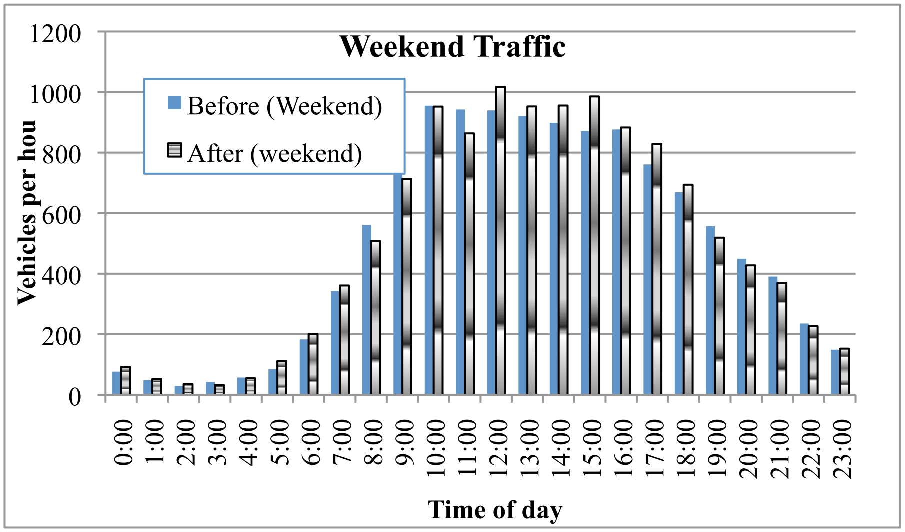

Figure 5 - Comparison of before and during traffic volumes on weekends

It should be noted that, on the second day of the lane closure (Friday May 16, 2008) between 7:00 to 9:00 AM there was about 50% traffic diversion. However, the diversion decreased during the later part of the day (Figure 6). The reduction in traffic volume decreased significantly after 4:00 AM, this we believe is mainly due to the drivers returning to Burlington for a weekend.

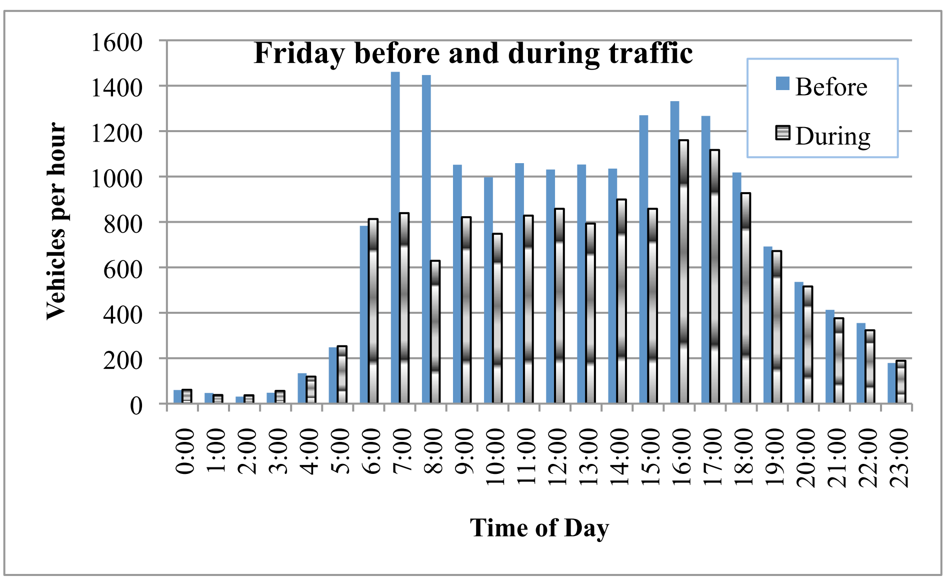

Figure 6 - Traffic comparison on the second day of lane closure

The before construction speed data is collected for both passing and through northbound lanes. During construction the passing lane was closed. For the purpose of comparison, we combine both passing lane and through lane speed data. The speed is not available in absolute values but in ranges, as shown on the horizontal axis of Figure 8 and Figure 9. The plots show that there are not significant differences in the vehicles speed on weekdays and weekends. In the absence of the work zone, on a weekday about 83% of vehicles moved at a speed between 61 to 75 mph. During the construction activities about 72% of the vehicles moved at a speed between 41 to 45 mph. The speed during construction is much higher than the speed anticipated by VTrans officials.

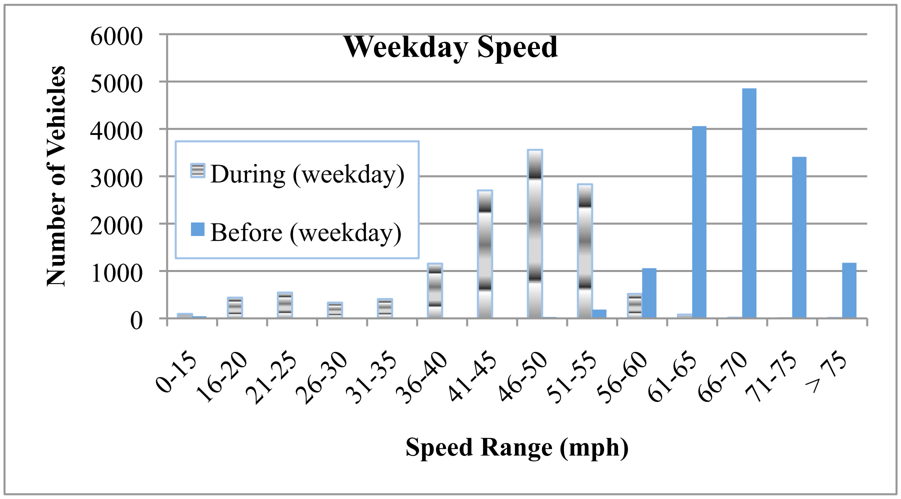

Figure 7 - Comparison of before and during speed on weekends

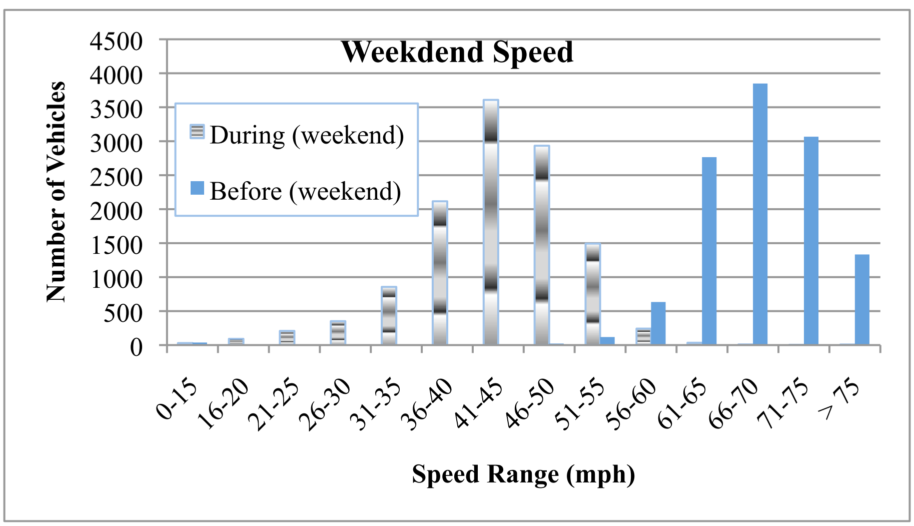

Figure 8 - Comparison of before and during speed on weekday

7. CONCLUSIONS

The results presented in the study and our own observations demonstrate that regional microscopic simulation models are capable of modeling the complex traffic conditions and driver behavior at a work zone and its vicinity. The models help in understanding the capacity, speed, flow and other variables under various control strategies. Thus, it is an appropriate tool for agencies interested in evaluating traffic impacts of work zones, especially those that require lane(s) closure for a longer period.

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