An Investigation into the Application of Dynamic Merge Control in Work Zones: A Simulation Study

by

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ABSTRACT

With increasing highway traffic volume, construction and maintenance works are quite frequent. Upstream lane merging manoeuver and capacity bottleneck can result from a work zone lane closure, which pose increased safety risk and reduced traffic flow efficiency. Dynamic Merge Control is an application of Intelligent Transportation Systems (ITS) technology in work zones, which is expected to improve the safety and mobility of the through traffic movement by governing the lane change manoeuver of vehicles from closed lane to the open lanes. The objective of this study is to examine the effectiveness of the two forms of Dynamic Merge Control in work zones, the dynamic early merge and dynamic late merge, in comparison with the conventional lane closure scheme according to MUTCD. The measures of effectiveness to compare the three strategies are vehicle throughput and delay. Dynamic early merge encourages drivers to merge from the closed lane to the open lanes well in advance of the work zone lane closure to lower the chance of friction between the vehicles in the open lane and merging vehicles at the merge point of a lane closure. On the contrary, dynamic late merge encourages drivers to make the full use of roadway storage capacity by encouraging them to go all the way and merge immediately before the work zone taper. To evaluate the efficiency of a traffic system, micro-simulation models have been proved to be very effective in lieu of field study. Therefore, a micro-simulation model of a two-to-one freeway lane closure has been developed in the traffic micro-simulation software VISSIM. The layout of the dynamic merge control is varied by manipulating the number of dynamic message signs and the spacing between the signs. Then the layouts were tested under different traffic demands, and sensors’ threshold occupancy rates. After running a thorough statistical analysis, it was obtained that if the traffic demand volume is less than 2000 vehicles/hour, then irrespective of the truck percentages and measures of effectiveness, conventional merge performs significantly better than dynamic merge control. When the measure of effectiveness is vehicle throughput, the dynamic late merge is found to perform significantly better than conventional merge only in the case of high heavy vehicle percentage. On another note, if delay is the determining criterion for the performance and selection of temporary traffic control, then irrespective of the truck percentage, dynamic early merge performs significantly better than dynamic late merge.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MOE	Measures of Effectiveness
DMS	Dynamic Message Sign
VAP	Vehicle Actuated Programming
DOT	Department of Transportation
VSL	Variable Speed Limit

CHAPTER ONE

INTRODUCTION

With increasing highway traffic volume, construction and maintenance activities take place frequently on highways. Lane closures are often necessary due to the presence of work zones in highways for different intervals of time; therefore, the capacity of the roadway is reduced during that period. As a result, vehicles passing through the work zone must merge from the closed lanes into the open lanes upstream of the work zone activity area. This whole maneuver of lane-merging poses safety risks, thus raising the likelihood of highway conflicts and crashes. Moreover, the resulting capacity bottleneck reduces the mobility of traffic in the roadway as well as creating congestion especially in the peak hours of traffic or when the traffic demand is high. This reduction in mobility mainly results in the form of increased delay and decreased throughput. In addition to these, frustration and rage among drivers passing through work zones are also consequences of occurrence of congestion. Vehicles often use the closed lane to go past the vehicles which are stuck in the open lane due to congestion, and cut through them to merge into the open lane at the last moment. This incident is a significant cause of road rage among the drivers in the closed lane. Moreover, if the queue of congestion extends upstream of the advance warning signs, the driver may not be aware of the work zone downstream, and due to this secondary crash may take place.

In 2013, 579 people were killed in work zone crashes in the United States, out of total 32,719 fatalities in road crashes, according to the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA) (NHTSA, 2013). Therefore, about 1.8% of the total fatalities took place in work zones in the United States. According to *Alabama Traffic 2012 Crash Facts,* there had been 128,307 crashes in Alabama in the year 2012; among those 2,232 were related to work zones, which is about 1.74% of overall crashes (Alabama Department of Transportation, 2012). There were 23 fatal incidents of work zone crashes in Alabama. In the report the following table is provided which shows the percentage of crashes according to the severity of the crash in work zones.

Table 1 - Crash Severity and Number of Crashes in Work Zones in Alabama

Crash Severity	Crashes in Work Zones
Property Damage	1,698 (76.0%)
Injury	477 (21.0%)
Fatal	23 (1.0%)
Unknown	34 (2.0%)

Source: (Alabama Department of Transportation, 2012)

State Departments of Transportation (DOTs) are looking for ways to improve safety and capacity of roadways in work zones, and Intelligent Transportation Systems (ITS) has proved to be an effective tool. According to FHWA’s Intelligent Transportation System Architecture and Standards, Intelligent Transportation System is the electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of surface transportation system (FHWA, 2001). Moreover, Federal Highway Administration (FHWA) conducted a study on the benefits of ITS at five sites at five different states; North Carolina, Arkansas, Michigan, Texas and the District of Columbia (Luttrell, et al., 2008). Some of the key benefits they found include reduction in aggressive maneuvers in work zones, significant traffic diversion rates in response to appropriate messages displayed, and improved ability to react to stopped or slow traffic.

To encounter the difficulties arising from lane-closures in work zones, different DOTs have been deploying several ITS-based countermeasures to improve safety and mobility. ITS-assisted measure dynamic merge control system has already attained much acceptance among the DOTs. Dynamic merge control in work zones can take two forms; dynamic early merge and dynamic late merge.

On a different note, road rage in work zone lane closures had been able to grasp substantial attention in recent years. Common causes of road rage such as weaving unsafely through traffic, cutting in line or driving on shoulders are likely to instigate aggressive driving behavior due to drivers' frustration which might cause severe safety hazards. As a countermeasure of road rage in work zones, dynamic merge control can play a significant role as suggested by Walters et al (Walters, et al., 2001). In the case of conventional merge control vehicle are expected to merge from closed lanes to open lane over a range of distance, on the contrary, in the case of dynamic merge control vehicles merge at a certain point. Therefore, oncoming vehicles upstream of the work zone taper are expected to be aware of merging vehicles in front of them at certain points along the corridor, which is likely to mitigate road rage.

1.1 EARLY MERGE

The main principle of the early merge strategy is to encourage merging of the vehicles from closed lane to open lanes well in advance of the work zone taper. This process has lower chances of friction than if vehicles would merge at the point right before the lane closure. This technique is accomplished by the use of additional signage and markings further upstream than the conventional guidelines according to Manual on Uniform Traffic Control Devices (MUTCD). The early merge technique can take two forms: static and dynamic (McCoy, et al., 1999).

The static form of early lane merge is not sensitive to traffic conditions in real time. The lane changing instructions remain constant regardless of the traffic condition in the work-zone. The static early merge strategy is usually implemented by placing additional advance lane closing signs at approximately 1-mile intervals for several miles in advance of the lane closure. The Indiana Department of Transportation developed and installed the Indiana Lane Merge Control System (ILMS), which is one of the earliest applications of dynamic early merge strategy. This system consists of a series of static and dynamic signs which create a changeable no-passing zone to force the vehicle to merge into the open lane. The static signs read "DO NOT PASS." The dynamic signs read "DO NOT PASS WHEN FLASHING." The system usually consists of multiple dynamic signs making sure the no-passing zone is sufficiently long. Except for the last dynamic sign, all the other dynamic signs are provided with a detector. When the traffic backs up to a certain sign, the detector sends a signal to the next sign which is then activated, as a result, the no-passing zone increases in length.

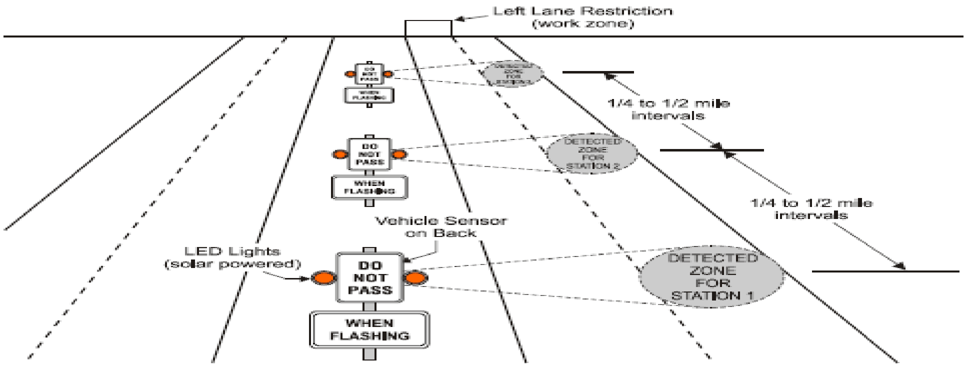


Figure 1 - Indiana Lane Merge Control System (Tarko, et al., 1998)

1.2 LATE MERGE

The principle of late merge is derived from the concept of utilizing the roadway storage capacity to its fullest by letting the drivers use all available traffic lanes up to the merge point upstream of the lane closure taper. The vehicles in the closed lane merge into the open lane right before the merge point. This combination of full-use of roadway storage capacity and orderly merge are expected to increase throughput, decrease travel times, and enhance safety. Dynamic late merge is the application of ITS technology in the late form of lane merging.

McCoy et al. proposed the use of dynamic late merge in work zones when congestion builds up. They proposed a work-zone traffic control plan which would work as conventional merge during periods of uncongested flow, but during periods of congested flow it would turn into late merge, by taking real-time measurements of traffic demand, occupancy rate or speed into consideration (McCoy, et al., 1999). According to their work, the Dynamic late merge would consist of a series of advance warning signs which would be activated when the detectors locate congestion in the open lanes and the signs would read, “USE BOTH LANES TO THE MERGE POINT.” When the congestion dissipates, the late merge system would be deactivated and the conventional system would be reinstated. They proposed to use signs with traffic detectors embedded with the signs. Maryland State Highway Administration developed the following set-up of late merge control strategy and deployed it along southbound I-83 in Northern Baltimore County on a test basis.

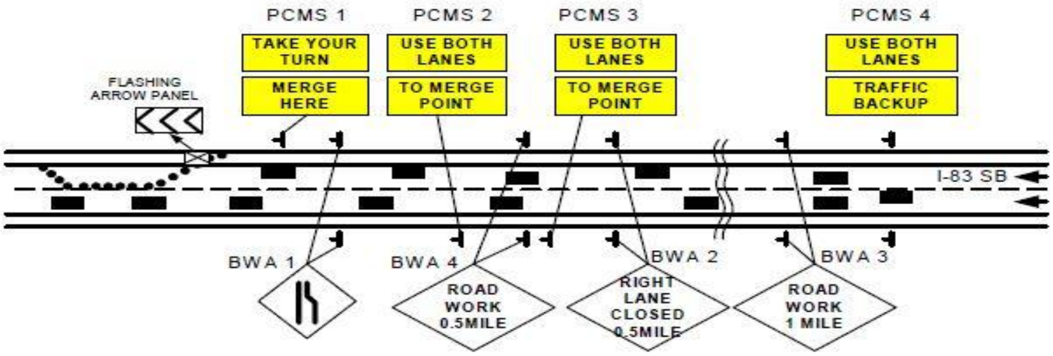


Figure 2 - Dynamic Lane Merge Set-up by MDOT (Chang, et al., 2005)

1.3 TRAFFIC SIMULATION

As it is not always feasible to obtain data from a field study which exactly emulates the design of a transportation system, with the advancement of computer technologies, microscopic simulation models have been performing a significant role in analyzing the effectiveness of a transportation system under various scenarios. Common microsimulation tools are VISSIM, CORSIM, AIMSUN etc. In this study, a micro-simulation model of a two-lane (one direction) freeway segment has been developed in the traffic micro-simulation software VISSIM.

1.4 OBJECTIVE OF THE STUDY

The central focus of the study is to investigate the effectiveness of the application of dynamic merge control in work zones and compare the effectiveness with the conventional merge according to MUTCD. The objectives of the study are following:

1. Conduct a thorough literature review of previous applications of dynamic merge control in work zones;
2. Develop a micro-simulation model of a two-to-one freeway work zone lane closure and deployment of dynamic merge control system in the work zone;

3. Collect data of vehicle throughput and delay from the simulation model runs under different traffic demand and different set-up of dynamic merge control system;
4. Run statistical analysis to figure if the dynamic merge control performs significantly better than the conventional lane closure under identical scenario;
5. Develop an optimal setting of threshold occupancy rate of sensors' placed alongside the signs which produces statistically the best output;
6. Propose an optimal layout of the dynamic merge of number of signs and spacing between the signs which produces statistically best output under certain traffic demand;
7. Develop recommendations of application of dynamic merge control in work zones which can be useful for the department of transportations.

1.5 OUTLINE OF CHAPTERS

Chapter Two provides an introduction to the different practices of dynamic merge control across the country by the DOTs and findings of the previous works on the topic. Moreover, it also presents a brief introduction to the conventional merge according to MUTCD. Chapter Three mainly discusses the methodology of the study. It provides a broad explanation of how the models are developed in VISSIM, how the data of the measures of effectiveness are collected, and finally how the statistical analysis is performed on the collected data. Chapter Four provides a detailed description of the data collected and the findings of the statistical analysis performed. Chapter Five concludes the thesis with findings and recommendations developed from the analysis phase, and a few proposals for future studies. .

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly focuses on the major investigations previously conducted on the application of dynamic merge control in work zones. This chapter highlights the objectives of the previous works, the methodology followed, and major findings of the works.

2.2 PREVIOUS WORKS ON DYNAMIC EARLY MERGE

Tarko et al. (Tarko, et al., 1998) conducted a study on the Indiana Lane Merge System (ILMS) which is a form of dynamic early merge which is conceptualized by Indiana Department of Transportation (INDOT). The main focus of the research was the drivers' compliance with the system, delays and travel times on approaches to work zones, optimal configuration of the system, and warrants for the system's use. To accomplish the goals of the study, a simulation model is developed using the programming language C++. Two freeway work-zones on I-69 and on I-74 near Indianapolis were selected for data collection of flow rate and speed of traffic in order to calibrate and evaluate the model. Data were collected in two phases; without dynamic merge controls and with dynamic merge controls. Traffic control mainly involved the DO NOT PASS boards, which are dynamic in nature and are activated by high occupancy of the detectors placed downstream. After the completion of the data collection process, the model was calibrated in several phases. The model was calibrated with the collected data and then validated which showed the reasonableness of the model. The simulation of the calibrated model was conducted run for the traffic demands and it was observed as expected that the travel times were increasing with the growth of traffic demand. On the other hand, the average deceleration rate was decreasing with the increase in traffic demand. The deceleration maneuver was deemed as a response to the risk of crash since no crash records were available related to the use of ILMS. Then the simulation was run with traffic controls of up to eight dynamic message signs. The purpose of the simulation was to determine the number of activated boards for each traffic demand and the optimal spacing between the boards. Travel time in the continuous lane and reduction in the number of passing maneuvers are the two determinants for this purpose. They proposed using the maximum number of dynamic message signs, using equal spacing in between the dynamic message signs, and setting the threshold detector occupancy rate to 30%.

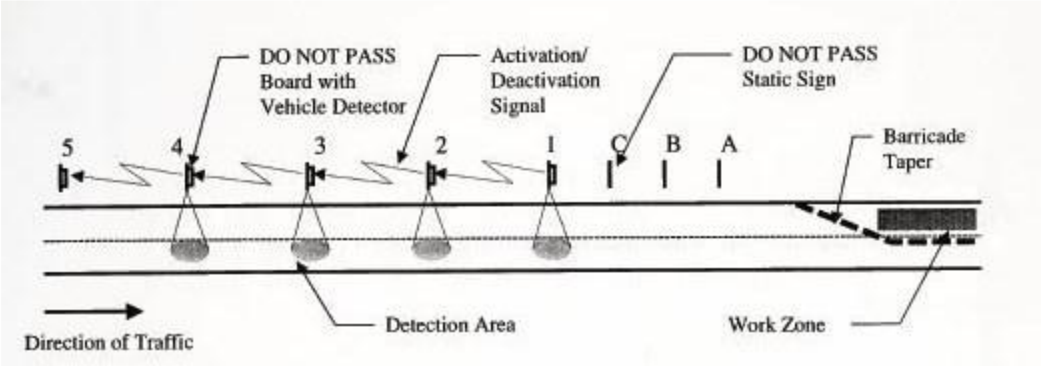


Figure 3 - Layout of ILMS (Tarko, et al., 1998)

Tarko et al (Tarko, et al., 2001) conducted another study on the safety and capacity evaluation of the Indiana Lane Merge System. As the system was still a relatively new concept, and was not tested in a real construction zone environment, that worked as the motivation of this study.

Michigan Department of Transportation (MDOT) developed maintenance of traffic (MOT) plans in work zones known as lane merge traffic control system (LMTCS). A detailed study on the applicability and effectiveness of the system was undertaken by Datta et al (Datta, et al., 2001). The LMTCS is a form of dynamic early merge. In this study, dynamic LMTCS was implemented at four locations initially, and three more locations afterwards. The researchers found the LMTCS to be very effective in reducing aggressive driving behavior, increasing safety, and reducing delay. They recommended using five DMS with one changeable message sign with text “Merge Right” (or Left) with an arrow symbol.

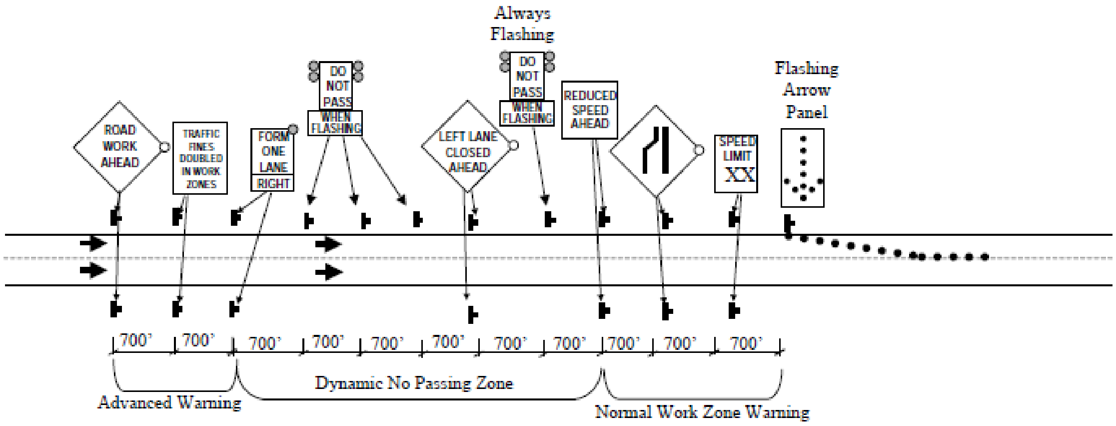


Figure 4 - Layout of LMTCS (Datta, et al., 2001)

2.3 PREVIOUS WORKS ON DYNAMIC LATE MERGE

The first idea of late merge was proposed by the McCoy et al. (McCoy, et al., 2001). They proposed a scheme of swap between conventional merge and dynamic late merge depending on the traffic condition in temporary traffic control zone. In high-speed, low-volume conditions, chances of crashes are higher as drivers might face confusion about the merge point. Because of this safety concern, the researchers discouraged the use of late merge during off-peak periods. They suggested the conversion of conventional merge to late merge during peak-periods or when congestion occurs. According to their strategy, the dynamic late merge would consist of a series of advance signs which would be activated when the sensors would detect congestion on the highway and ask the drivers to use both lanes till the merge point. When the congestion diminishes, the signs would be deactivated and traffic management would return to the conventional method.

The transportation research group at Wayne State University (Datta, et al., 2007) evaluated the effectiveness of dynamic late lane merge system (DLLMS) on three freeway segments in Southern Michigan. The DMS are activated if the average speed of the traffic exceeds 35 mph or 45 mph. On two test sites the threshold value was set to 45 mph, and on the remaining one it was set to 35 mph. They found a statistically significant difference in mean delay and mean travel speed between DLLMS and conventional merge. They recommended the use of the system if the traffic demand volume is greater than 1,800 vehicles per hour before the beginning of construction. They also recommended using four dynamic message signs including typical lane closure static signs.

Beacher et al. (Beacher , et al., 2005) conducted a study comparing the performance of late merge to conventional merge. In VISSIM, simulation models were developed of both type of traffic controls. Both type of traffic controls were tested under different traffic demand volume, truck percentage, lane closure configuration and desired free-flow speed. They recommended use of late merge in two-to-one or three-to-two lane closure configuration of the heavy vehicle percentage is at least 20% for numerical increase in vehicle throughput.

2.4 PREVIOUS WORKS ON COMBINATION OF EARLY AND LATE MERGE

Radwan et al. (Radwan, et al., 2009) conducted a review analyzing the ITS-based lane merging schemes in a temporary traffic control zone. In the paper, the authors presented an extensive study of the various dynamic lane merge applications across the United States of both forms of merging, i.e. early and late. These schemes include large-scale installation and calibration of a large number of equipment. Therefore, the authors believe that these schemes may not be appropriate for short-term work zones where the setup of the work zone shifts on short intervals (e.g. less than 2-3 days). The Florida Department of Transportation expressed their interest in incorporating and testing ITS-based lane merge schemes into short-term work-zones. FDOT utilizes a system called Motorist Awareness System (MAS) to apply in the short term work zones. The MAS includes an advance warning arrow panel at the beginning of work zone taper, one portable changeable message sign (PCMS), two portable regulatory signs (PRS) with flashing beacons which highlight the regulatory speed for the work zone, two radar speed display units (RSDU) which display the motorist's work zone speed, and other regulatory signs. The authors proposed the addition of one portable message sign, which would define whether the system is an early or late merge system, and one sensor trailer to the current MAS system with the purpose of easing equipment relocation, installation and calibration. Therefore, the suggested dynamic lane merging system by the authors includes traffic detection stations, 1 central computer base station, wireless communication links and portable changeable message signs.

Zaidi et al. (Zaidi, et al., 2012) also conducted a study on the effectiveness of six different MOT plans through developing simulation models in VISSIM. The objective of the study was to determine the effectiveness of the MOT plans based on throughput and travel time. One of those six MOTs is the conventional MOT plan of Florida which is Motorist Awareness System (MAS), and the other five are different combinations of the two of the most-common ITS applications around the work zone, Variable Speed Limits (VSL) and early and late form of Dynamic Lane Merge (DLM). The MOT plans investigated in the study are the conventional plan in Florida, the early Dynamic Lane Merge, the late Dynamic Lane Merge, the combination of VSL and MAS, the combination of VSL and Early DLM, and the combination of VSL and Late DLM. The effectiveness of these measures is tested under different drivers' compliance rate, under different truck percentages and under different traffic demand volumes. For compliance rate, the plans are evaluated under 20%, 40% and 80% of the drivers' compliance rate. The MOTs were also evaluated under 10%, 20% and 30% of traffic as heavy vehicles. The MOTs were also simulated under traffic demand volumes of 500, 1000, 1500, 2000 and 2500 veh/hr. After obtaining the throughputs and travel time through simulation using VISSIM, a statistical analysis was performed to determine if statistically significant differences exist between the throughput means. For this purpose Tukey's comparison was used. It was found that if the traffic demand volume is less than 500, 1000 or 1500, there was no significant difference in the mean throughputs of all compliance rates and truck percentages. In the case of travel time, after running the statistical analysis, they found that no significant difference existed in mean travel times if the traffic demand volume was less than either 500 or 1000. If the traffic demand volume was high (2000 or 2500 veh/hr), throughputs produced due to early DLM, late DLM, combination of early DLM and VSL, combination of late DLM and VSL are significantly higher. The authors also found that the addition of VSL to the DLM did not improve the throughput and travel time compared with the DLM without VSL. They also found that work zones with the MOT MAS and only VSL had the worst performance of all the MOTs.

Harb et al. (Harb, et al., 2012) conducted a similar study comparing the effectiveness of three lane merging techniques based on throughput volume and travel time by simulating a two-to-one work zone lane closure in VISSIM. The research team at the University of Central Florida added ITS technologies to the existing MAS plan in Florida, which resulted in the production of two lane merging techniques which are the early and late form of the Simplified Dynamic Lane Merging Systems (SDLMS). This work compared these two ITS-based lane merging schemes and the conventional lane-merge on freeway work zones. Each technique was analyzed as well as simulated based on different levels drivers' adherence to the regulations, different levels of truck percentages in the traffic, and different levels of traffic demand volumes. There were 60 combinations of 4 levels of compliance rates, 3 levels of truck percentagess, and 5 levels of traffic demand volumes. The authors also performed statistical analysis to determine if there is statistically significant differences among the mean travel times and throughputs. Statistically significant difference was not observed in throughput if the demand volume is less than 1500 vehicles per hour in all combinations of compliance rates and truck percentages. The authors also observed that if the demand volume is 2000 or 2500 early SDLMS outperformed MAS and late SDLMS in most of the combinations. In most of the combinations, early SDLMS has significantly lower travel time than MAS and late SDLMS.

Pesti et al. (Pesti , et al., 2008) conducted a study on identifying effective ways to improve traffic operations and safety in work-zones with lane closure. They evaluated the dynamic lane merge concept by using micro-simulation software (VISSIM), and developed recommendations based on the findings from the simulation. They evaluated the concept in ten different lane configurations, and simulation test-beds were developed for each configuration. The Vehicle Actuated Programming (VAP) was used to implement the dynamic lane merge concept in the micro-simulation model. In order to determine the effectiveness of each lane configuration, each simulation test-bed went through a series of runs with a range of traffic demands and various random seed numbers. The measures of effectiveness were vehicle throughput, travel time and delay. The researchers found that the dynamic merging concept may not work as well as intended in all lane configurations. From the simulation model, it is obtained that the dynamic merge may only perform well in the lane closure configuration of 2-to-1, one configuration of the 4-to-1, and one configuration of the 4-to-2.

Kurker et al. (Kurker, et al., 2014) evaluated the effectiveness of Fixed-Cycle Signal Merge Control (FCSMC). FCSMC is the late merge traffic control strategy which consists of fixed cycle lengths. These cycle lengths consist of green, amber and red intervals. The model was developed using both CORSIM and VISSIM. In CORSIM, at first a base-scenario of late merge was modeled without signalized operations. Then one signal per lane was placed and signals ran one at a time for the 2-to-1 and 3-to-1 configurations in 30, 60, 90,120, 150, and 180-second cycle lengths. For 3-to-2 configuration, signals ran for two lanes operating at a time. In VISSIM, the fixed cycle lengths were 30, 60, 90 and 120. In both cases, there were different runs for traffic volumes of 1800, 2000, 2200, and 2400 veh/hr/ln. After running the simulation, the researchers conclude that lower demand is best managed by early merge, low to moderate demand by late merge and high demand by signal merge. They discouraged using short cycle lengths such as 30 seconds. For this research, they collected field data from one site on I-610 in Houston, and two sites on I-35 in Austin.

McCoy et al. (McCoy, et al., 1999) conducted a thorough evaluation of twelve alternatives of traffic control measures at work zones of rural freeways. The traffic control scheme alternatives were the product of literature review, brainstorming sessions, and survey of other states. At the first phase of the project, NDOR (Nebraska Department of Roads) Merge, which is the conventional traffic control plan in Nebraska, was evaluated by collecting field data at two locations. Another purpose of the field study was to calibrate the traffic flow models developed later. The data collected from field study include lane distribution, speed of traffic, vehicle headway distribution, traffic conflicts, traffic volume, and density. The researchers used three models; two of them were FRESIM and FREFLO, both of which are developed by FHWA, and one other model Work Zone Simulation Model (WZSIM) developed by themselves. The simulations were run for three traffic demand volumes; 1000, 1500 and 2000 veh/hr. The researchers found from simulation study that the early merge causes less delay than the conventional NDOR Merge at all three volume levels. The late merge also causes less delay when the traffic demand volume is either 1500 or 2000 veh/hr, but in the case of 1000 veh/hr the delay increases. The authors remarked that based on delay, the late merge and early merge are the best strategies. They also concluded with similar kind of remark while comparing different merging schemes in terms of throughput volume.

2.5 CONCLUSION

This chapter briefly highlighted the major studies conducted on the application of dynamic merge control in work zones. Moreover, this chapter also provided brief description of the methodology and major findings of the previous works. The findings and recommendations of the previous works were quite corroborative of each other. Dynamic early merge was suggested in the case of low-volume, high-speed highways to improve traffic safety. On the other hand, when the traffic demand goes past the capacity of highways, dynamic late merge was proved to be more efficient as suggested by most of the previous works.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter provides a detailed description of the steps undertaken in different stages of the research work from the beginning to the collection of results. This chapter discusses the reasoning behind the selection of tools in the research and also measures of effectiveness (MOE). Moreover, this chapter provides a brief summary of the multiple layouts of temporary traffic control under investigation and the effort to develop the corresponding models in VISSIM. In addition to these, this chapter also discusses about the simulation runs in VISSIM, and the statistical analysis of the results collected from the simulation runs.

3.2 TRAFFIC MICRO-SIMULATION TOOLS

To analyze the performance of a strategy in the transportation network, both deterministic and micro-simulation tools can be used. Deterministic tools are defined as those which assume that there is no variability in the driver-vehicle characteristics. An analysis performed using deterministic tools might be inaccurate as these tools are based on equations which have limitations when the network is at its full-capacity. Common deterministic tools which are used in the industry include Quickzone, Highway Capacity Software, and Synchro. With the advancement of computer technology, the use of traffic micro-simulation analysis tools like

CORSIM, VISSIM, or Simtraffic is growing among transportation practitioners and researchers. Federal Highway Administration's *Traffic Analysis Toolbox* defines micro-simulation as, "modeling of individual vehicle movements on a second or sub-second basis for the purpose of assessing the traffic performance of highway and street systems, transit and pedestrians" (Dowling, et al., 2004). Microscopic traffic simulation can be very effective in traffic operations to evaluate alternative solutions since it is capable of considering effects of microscopic characteristics of traffic like individual driver behavior or vehicle characteristics (Elefteriadou, 2014). On the other hand, with the help of traffic micro-simulation alternative solutions of a traffic problem can be evaluated with the absence of a field study.

VISSIM is a microscopic, time step and behavior based simulation model developed to model various scenarios of traffic operations (PTV Vision , 2011). Basically VISSIM consists internally of two different parts, which are exchanging detector calls and signal status through an interface. VISSIM uses the Wiedemann model (Higgs , et al., 2011) which states that the driver of a faster moving vehicle starts to decelerate as he gets closer to a slower moving vehicle influenced by his individual perception threshold. It is not possible by the following vehicle to determine the exact speed of the preceding vehicle, therefore the speed of the following vehicle at first falls below that vehicle's speed. The driver of the following vehicle starts to accelerate again when he reaches another perception threshold. This endeavor produces an iterative process of acceleration and deceleration. The traffic flow in the network is simulated by "driver-vehicle-units" i.e. every driver with a specific set of behavior characteristics is assigned to a specific vehicle with specific technical capabilities. In VISSIM, the stochastic nature of traffic is modeled by incorporating several parameters which have a distributions rather than a fixed value.

There are multiple parameters of the car following and lane change models in VISSIM. These parameters heavily influence the driving behavior within the network. If the Wiedemann 99 model is used then 10 model parameters are available. These parameters range from CC0 to CC9. For instance, CC0 refers to the desired distance between stopped cars. There are two kinds of lane change in VISSIM, necessary lane change and free lane change. If the necessary lane change option is used, the driving behavior parameters contain the maximum acceptable deceleration for the vehicle, and the trailing vehicle on the new lane. When the free lane change is used, VISSIM checks for the desired safety distance of the trailing vehicle on the new lane.

3.3 MEASURES OF EFFECTIVENESS

The measures of effectiveness to compare the different layouts of temporary traffic control were chosen after careful deliberation and consulting previous literature. Vehicle throughput was chosen as an MOE as it decreases along the freeway due to the reduction of lanes, reduced speeds and merging maneuvers which create shockwaves along the corridor. In this study, the vehicle throughput is the number of vehicles passing through the open lane of the activity area of the work zone per hour. The other performance measure which is used in this study is delay, which is directly associated with travel time. The collection of delay data is based on the travel time sections created in the VISSIM simulation model. In this case, delay is the difference between the ideal travel time through the work zone and the actual travel time, which is related to the posted speed limit of the highway (Elefteriadou, 2014). Delay is usually measured in seconds/vehicle.

3.4 CONVENTIONAL MERGE MODEL

A model of the application of temporary traffic control according to the direction of MUTCD in a two-to-one freeway lane closure configuration is developed in VISSIM. The purpose of this endeavor is to compare the performance of dynamic merge control system to the temporary traffic control according to MUTCD. In the literature of this work, the temporary traffic control according to MUTCD is regarded as the conventional merge.

The entire zone of the highway in which road user conditions are changed due to the presence of the work zone, is included in the temporary traffic control (TTC) zone. There are four components of the TTC zone (listed in the order encountered by traffic):

(1) Advance Warning Area
(2) Transition Area
(3) Activity Area
(4) Termination Area

The components of the work zone area are presented in Figure 3.1. The advance warning area is the section of the highway upstream of the work zone taper where the road users are informed about the upcoming work zone. The transition area is the part of the TTC zone where road users are diverted from their normal path into the path they must follow through the activity area. This area involves the use of tapers. The activity area is the part of the TTC zone where the activities of the work zone take place. The activity area includes both longitudinal and lateral buffer space, traffic space and work space. The termination area is the section where road users are returned to their normal path.

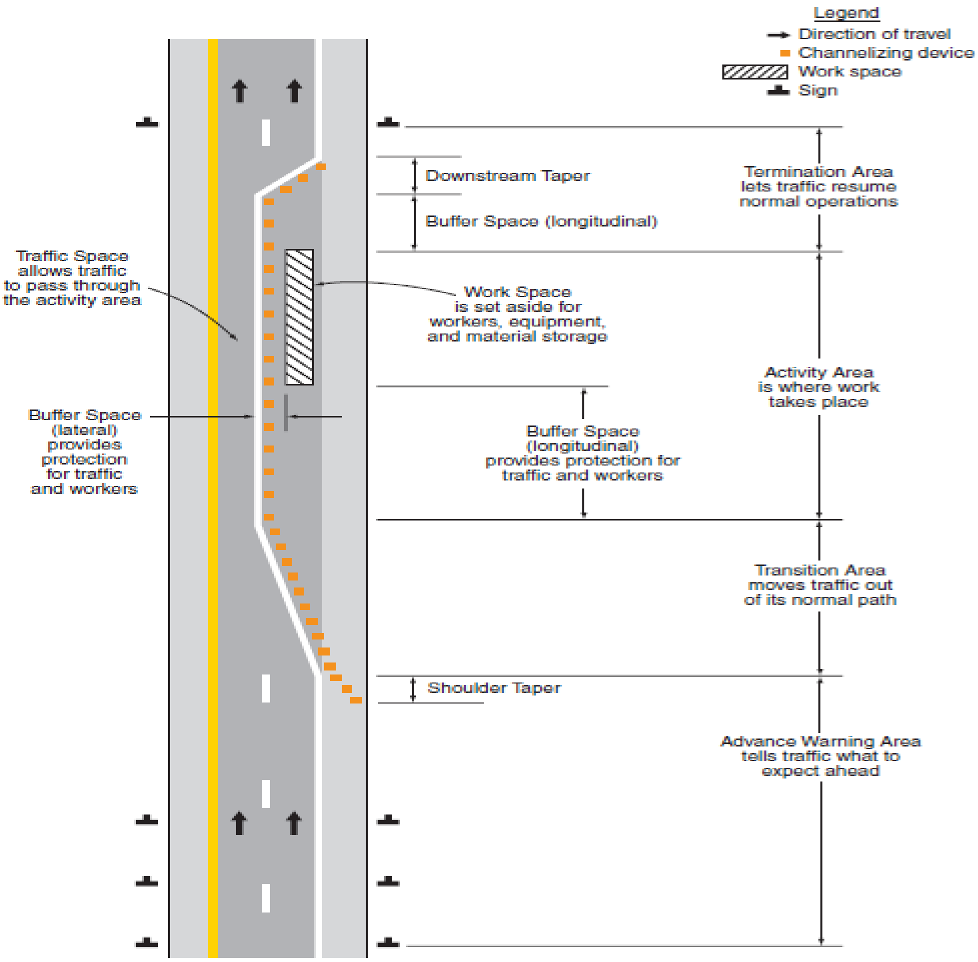


Figure 5 - Components of a Temporary Traffic Control Zone

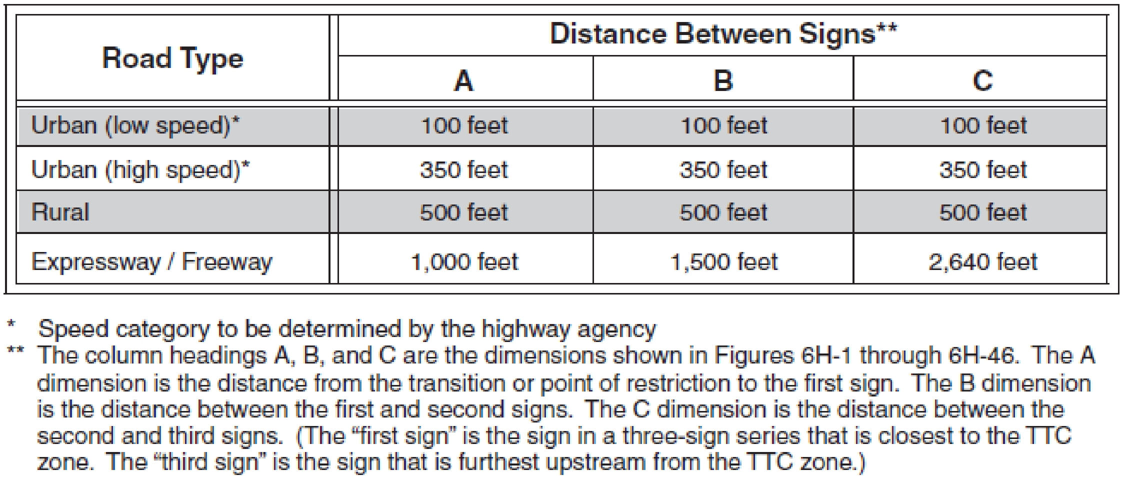
Source: (Federal Highway Administration, 2009)

The conventional merge model in VISSIM is developed by modifying the values of emergency stop distance and lane change distance of the connector connecting the work zone and freeway. In Table 3.1, the MUTCD recommended minimum spacing between the signs upstream of the work zone taper is presented. Moreover, the MUTCD recommended length of the merging taper is provided in Table 3.2. In addition to these, the minimum length of the merging taper is obtained from the following equation which is a function of posted speed limit in the freeway and width of lanes.

$$L = W*S \tag{3.4.1}$$

As the posted speed limit in the model is 70-mph and width of lane 12-ft, therefore the length of the merging taper is 840-ft, and the length of the downstream taper is taken to be 100-ft. In this study, the total length of longitudinal buffer space and the work space in the temporary traffic control zone is taken to be 1560-ft. Consequently, a total length of 2500-ft of the zone starting from the beginning of the merging taper to the downstream taper is mimicked in the model developed in VISSIM.

Table 2 - Recommended Advance Warning Sign Minimum Spacing



Road Type	Distance Between Signs**		
	A	B	C
Urban (low speed)*	100 feet	100 feet	100 feet
Urban (high speed)*	350 feet	350 feet	350 feet
Rural	500 feet	500 feet	500 feet
Expressway / Freeway	1,000 feet	1,500 feet	2,640 feet

* Speed category to be determined by the highway agency

** The column headings A, B, and C are the dimensions shown in Figures 6H-1 through 6H-46. The A dimension is the distance from the transition or point of restriction to the first sign. The B dimension is the distance between the first and second signs. The C dimension is the distance between the second and third signs. (The “first sign” is the sign in a three-sign series that is closest to the TTC zone. The “third sign” is the sign that is furthest upstream from the TTC zone.)

(Source: Federal Highway Administration, 2009)

Table 3 - Taper Length Criteria for Temporary Traffic Control Zones

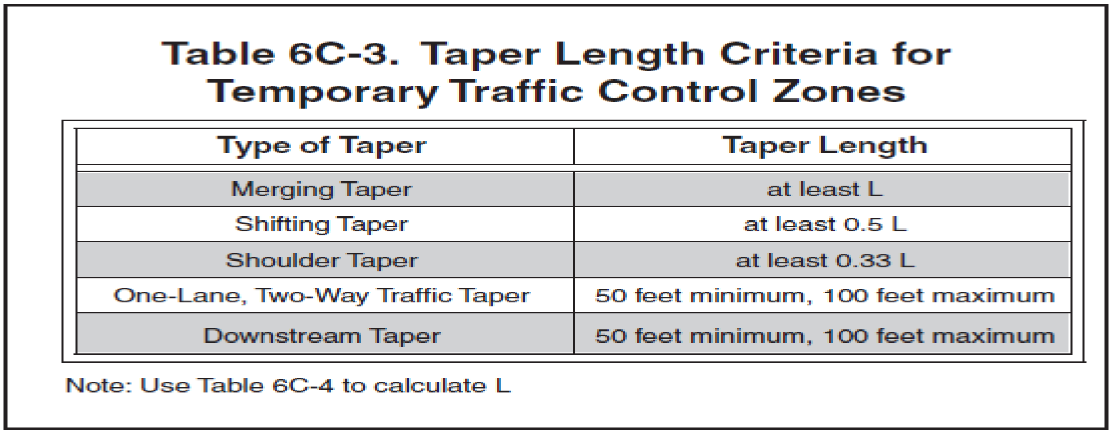


Table 6C-3. Taper Length Criteria for Temporary Traffic Control Zones

Type of Taper	Taper Length
Merging Taper	at least L
Shifting Taper	at least 0.5 L
Shoulder Taper	at least 0.33 L
One-Lane, Two-Way Traffic Taper	50 feet minimum, 100 feet maximum
Downstream Taper	50 feet minimum, 100 feet maximum

Note: Use Table 6C-4 to calculate L

(Source: Federal Highway Administration, 2009)

3.5 DYNAMIC MERGE CONTROL MODEL: SYSTEM DESCRIPTION

In the dynamic early merge, vehicles are encouraged to merge into the open lane well in advance of the work zone taper. In the dynamic late merge, vehicles are encouraged to merge into the open lane right before the work zone taper. In previous studies, the practice was to develop a layout of traffic control based on engineering judgment, and then investigate the effectiveness of that layout. In this study instead multiple layouts of both early and late forms of dynamic merge control are developed by varying the total number of dynamic message signs in the advance warning area and spacing between the signs, thus comparing these altogether with a view to developing an optimal layout under a certain traffic demand.

The layouts of dynamic merge control investigated in this work consist of a range of one to four dynamic message signs with a spacing between the signs of either 1/8 of a mile, 1/4 of a mile or 1/2 of a mile. It can be mentioned here that distance between the work zone taper and the first sign upstream of the work zone taper is equal to the spacings in between the signs in the temporary traffic control plan. When drivers enter the work zone area, they are provided information about the work zone by signs like "Road Work Ahead", "Traffic Fines Doubled in Work Zones". The first sign in the layout is always flashing, and sensors are placed alongside the remaining signs in the system to activate or deactivate.

In this study, the sensors' threshold occupancy rate is determined to be the criteria to activate or deactivate the dynamic message signs (DMS) upstream and downstream respectively. When the actual occupancy rate alongside a DMS exceeds the preset threshold occupancy rate, it sends a signal to the next upstream sign, and thus the next sign is activated. For instance, in the temporary traffic control the first sensor is located beside the first sign upstream of the work zone taper, and the actual occupancy rate at that location is the determining factor of activating or deactivating the second sign of the system. In this system, sensors are placed beside each sign other than the last sign upstream of the work zone taper. Therefore, it is very important to set the sensors at the threshold occupancy rate which yields the most efficient performance of the overall dynamic merge control system. In this study, three threshold occupancy rates of the sensors, 20%, 30%, and 40% were investigated to determine the optimal setting of the sensors' threshold occupancy rate. The threshold occupancy rates under investigation were chosen based on the reasoning that around those occupancy rates of the roadway congestion is likely to develop.

3.6 SIMULATION MODEL DEVELOPMENT

The model of the dynamic merge control system in VISSIM is developed basically using the links and connectors of two-to-one freeway lane closure configuration. The first step in the model development endeavor is to draw the links replicating the two-lane freeway. A long link consisting of two-lane of 12-foot each is drawn. To replicate the work zone, one lane is dropped and a one-lane link is created to replicate two-to-one lane closure. In VISSIM, connectors are created to join to links. The link replicating the work zone and the one replicating the freeway are connected by a connector. At the locations of the DMS upstream of the work zone taper, the link is split and the split link is connected by connectors for the convenience of declaring alternate routing decisions. A static route is assigned from the beginning of the network to the end to make certain that the number of vehicles entering the network is equal to the number of vehicles leaving the network. The messages of the dynamic message signs are conveyed to the vehicles by partial routing decisions. If re-distribution is required of vehicles which are under a static routing decision, partial routing is used. As in the model, vehicles under the static route are directed to change the route based on the activation of DMS, partial routing is used. The control logic of the dynamic merge control system is attached to VISSIM in a text file. Detectors are placed alongside all the signs in the system other than the last one in the series to detect the occupancy rates of the highway, and thus direct vehicles according to the control logic. Vehicle Actuated Programming (VAP) language of VISSIM is used to mediate between the route assignment and detectors. The vehicle actuated programming is an optional add-on module of VISSIM for the simulation of programmable, phase or stage based, traffic actuated signal controls (PTV GROUP, 2014). The lane change behavior of the vehicles is directed by the dynamic message signs based on the current occupancy rate of the highway at the location of the signs. The desired speed decision along the network is a range of 65-75 miles per hour.

In this work, simulation models are developed to figure out the effects of the variables on the MOEs. The variables examined are the number of dynamic message signs, the spacing between the dynamic message signs, traffic demand volume, truck percentage, and the threshold occupancy rate of the sensors. In both forms of the dynamic merge control system, these variables are modified within the selected range, and the effect is observed by the collection of the values of MOEs. In the case of conventional merge, only the values of traffic demand volume and truck percentage is modified.

Table 4 - Summary of Variables Examined in the Dynamic Merge Control System

Variables Examined	Number of Levels	Values of Variables Examined
Number of DMS	4	1
		2
		3
		4
Spacing between the DMS (mile)	3	1/8
		1/4
		1/2
Traffic Demand Volume (veh/hr)	4	1500
		2000
		2500
		3000
Truck Percentage (%)	3	10
		20
		30
Sensors’ Threshold Occupancy Rate (%)	3	20
		30
		40

3.7 REQUIRED NUMBER OF SIMULATION RUNS

As VISSIM is a stochastic model, it is necessary to conduct several runs in each case to obtain the mean value of the MOE which addresses the randomness of the models. Therefore, determining the required number of simulation runs is very crucial in the modeling effort. Too few simulation runs might not address the stochastic nature of the developed models. On the contrary, too many simulation runs might make the process of result collection tedious and redundant.

The Federal Highway Administration's guideline provided the following equation to (Dowling, et al., 2004) to compute the number of required simulation runs-

$$CI_{1-\alpha\%} = 2 * \ t_{(1-\alpha/2),N-1} \frac{s}{\sqrt{N}} \tag{3.8.1}$$

Where,

$CI_{(1\text{-alpha})\%}$ = (1-alpha)% of confidence interval for the true mean, where alpha equals the probability of the true mean not lying within the confidence interval;

$T_{(1\text{-alpha}/2),N\text{-}1}$ = Student's t-statistic for the probability of a two-sided error summing to alpha with N-1 degrees of freedom, where N equal the number of repetitions;

S = standard deviation of the model results.

To determine the required number of simulation runs, the equation provided by FHWA is modified by the Traffic Operations Analysis Tools of Virginia Department of Transportation (Virginia Department of Transportation, 2013) as following:

$$N = \frac{(Z)^2\,(S_S)^2}{E^2} \tag{3.8.2}$$

Where,

N = necessary sample size;

Z = The number of standard deviations away from the mean corresponding to the desired confidence level;

S = sample standard deviation;

E = tolerable error in terms of the sample mean.

This equation is based on the statistical process developed by FHWA to determine the appropriate number of simulation runs at the 95th percentile confidence interval.

Several samples each consisting of ten values of MOEs were selected from the overall population and it was found that the required number of simulation fluctuates around three, with a tolerable error of 3% of the sample mean. Consequently, it was decided to run each simulation with three random seeds.

In the case of dynamic early merge, 12 different layouts varying the number of DMS and the spacing between the DMSs is investigated under 12 different traffic demand volumes. Each combination obtained from the different layouts under different traffic demands are also investigated under 20%, 30%, and 40% sensors' threshold occupancy rate. Therefore, the total number of combinations for dynamic early merge taking all variable into account is 432. As three random seeds are used for each case, the total number of simulations of dynamic early merge is 1,296. Likewise, the total number of simulations for dynamic late merge is 1,296. The total number of simulations for conventional merge is 36 with three random seeds. Each simulation run is of 3900 seconds, with 300 seconds of initialization time.

3.8 CALIBRATION AND VALIDATION

It would be conducive to make decisions about the performance of dynamic merge control if the developed models are calibrated and validated. The simulation models are expected to predict more accurate traffic behaviors if the models are properly calibrated and validated. But due to the lack of work zones with the desired characteristics during the timeframe of this study, it was not possible to calibrate and validate the models in this work. Calibration and validation effort of the model can be a part of a future study. On the other hand, the goal of the project is to investigate the general performance of dynamic merge control. In this study, the scope is not bound in a specific scenario. Therefore, it is not mandatory to calibrate and validate the models for proper assessment of the performance of the traffic controls. The simulations were run and consequently results were collected under the default parameter values of VISSIM.

3.9 DATA ANALYSIS

The next step after data collection is to conduct a series of statistical analysis to obtain meaningful decisions about the application of dynamic merge control in work zones. Briefly, the objectives of running the statistical analysis on the collected data are following:

1) To determine an optimal setting of the sensors’ threshold occupancy rate;
2) To compare the means of the measures of effectiveness obtained from all layouts of temporary traffic controls under identical traffic demand to determine which system works best in a certain situation;
3) To develop a multiple linear regression model which can predict the outputs under a certain temporary traffic control and traffic condition. Additionally, the linear regression model would help to determine the significant factors affecting the measures of effectiveness.

The statistical analysis in this study is performed in the software Statistical Package for the Social Sciences (SPSS) entirely.

3.9.1 DETERMINING THRESHOLD SENSOR OCCUPANCY RATE

In this study, three threshold occupancy rates of the sensors, 20%, 30%, and 40% were investigated to determine the optimal setting of the sensors' threshold occupancy rate. Therefore, the first step in the statistical analysis part of the project is to determine the relationship between the threshold occupancy rate of the sensors and the measures of effectiveness. To determine the correlation, three dummy variables are declared indicating each threshold occupancy rate. In the dummy variables, 1 indicates that the detector threshold occupancy rate is set to that particular occupancy rate, and 0 indicates that it is of any other occupancy rate. To check if there is any correlation between the dummy variables and MOEs, box plots are obtained in SPSS. In the x-axis of the box-plot the dummy variable and in the y-axis the respective MOE is plotted.

3.9.2 COMPARISON BETWEEN CONVENTIONAL MERGE AND DYNAMIC MERGE

In this study, different layouts of dynamic early merge, dynamic late merge, and conventional merge are tested under a set of different traffic volumes and truck percentages. A total of 25 different layouts of temporary traffic controls; 12 combinations of dynamic early merge, 12 combinations of dynamic late merge, and conventional merge, are under examination in this study. The combinations vary in their respective number of signs and spacing between the signs. The traffic controls are under traffic volume of 1500, 2000, 2500 or 3000 vehicles/hour. In each case, the traffic volume has a truck percentage of 10%, 20% or 30%. The effectiveness of the different layouts under a certain condition is judged based on two measures: vehicle throughput and delay. A series of statistical tests are performed on the collected data under a certain vehicle composition to determine the most effective temporary traffic control.

The first step in determining the layout which has the best performance, a one way ANOVA is conducted. The null hypothesis of the one-way ANOVA is that the mean throughputs or delays under all layouts of temporary traffic controls are not different from each other statistically at a significance level of 0.05. The alternative hypothesis of the ANOVA was that at least one of the mean vehicle throughputs or delays are not equal to other means statistically. The null hypothesis is rejected if the p-value obtained after the ANOVA is less than 0.05. If the null hypothesis is rejected then Tukey's multiple comparison test is conducted to determine the layout which has a statistically significant different output than conventional merge.

3.9.3 REGRESSION ANALYSIS

The final step in the statistical analysis on the collected data is to conduct a multiple linear regression in which the dependent variable would be any of the measures of effectiveness. Traffic volume and truck percentage is the independent variable. In addition to these, dummy variables are declared for all the 24 different layouts of dynamic merge control varying the number of signs and spacing between the signs, and those are included in the model. For instance, if vehicle throughput is the dependent variable, the equation would take the following form:

X_n = 1 if the temporary traffic control n is used (n = 1, 2, 3, …………..,24)

$$\text{Vehicle Throughput} = \beta_0 + \beta_{DV}*(\text{Traffic Volume}) + \beta_{TP}*\text{Truck Percentage} + \sum\beta_n*X_n$$

3.10 CONCLUSION

This chapter explained the key stages and steps undertaken during the entire research work. This chapter provided reasoning behind the methods of the research as well as a detailed description of the simulation models development. Moreover, it provides an elaborate description of the statistical analyses performed to obtain the findings.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 INTRODUCTION

Chapter Four presents the results obtained by the research methodology, and the procedure of analysis which followed the collection of results. This chapter discusses how the data of the measures of effectiveness are collected under varying temporary traffic controls and traffic volumes. In addition to these, this chapter also provides an explanation about the methods of data analysis and how the findings are obtained through the analysis.

4.2 DATA COLLECTION

The measures of effectiveness in this study were selected to be vehicle throughput and delay. Data of vehicle throughput are collected by placing three data collection points along the stretch of the simulated work zone. The detailed diagram of the data collection points are provided in Figure 4.1. The data collection points are set at distances of 500-ft, 1250-ft, and 2000-ft respectively downstream of the beginning of work zone taper. It was observed after the completion of data collection maneuver, that the difference between the values of the three points is very narrow. Thus, only the values of vehicle throughput obtained from the middle data collection point downstream of the work zone taper is included into the data analysis procedure. Table 4.1 provides a sample of values of vehicle throughput of few simulation model runs. The purpose of the table is to illustrate the narrowness of values of the data collection points with the help of standard deviations of a sample of simulation model runs.

Table 5 - Random Sample of Vehicle Throughput from Data Collection Points

Simulation Run No.	Vehicle Throughput (Vehicles/hour)			Mean (Vehicles/hour)	Standard Deviation (Vehicles/hour)
	Point 1	Point 2	Point 3		
1	1515	1511	1506	1511	4.51
2	1582	1580	1579	1580	1.53
3	1503	1496	1491	1497	6.03
4	2012	2002	1994	2003	9.02
5	2011	2008	2006	2008	2.52
6	1893	1888	1885	1889	4.04
7	2256	2247	2239	2247	8.50
8	1978	1970	1963	1970	7.51
9	1940	1933	1926	1933	7.00
10	2212	2217	2217	2215	2.89
11	1998	1996	1992	1995	3.06
12	2007	2009	2007	2008	1.15
13	1484	1489	1493	1489	4.51
14	1463	1463	1463	1463	0.00
15	1542	1538	1531	1537	5.57

A travel time section is declared in the models in VISSIM which starts at the beginning of the work zone taper, and ends at the end of downstream taper. From the travel time section, data of travel time, and delay are obtained.

Each simulation model run was of 3900 seconds with an initialization period of 300 seconds. Adding an amount of initialization period to the total time of simulation model run is significant as the simulation model runs starts with zero vehicles on the network. From manual observation of the model runs, it was reaffirmed that network reaches equilibrium during this initialization period. This initialization period is excluded from the period of data collection (Dowling, et al., 2004).

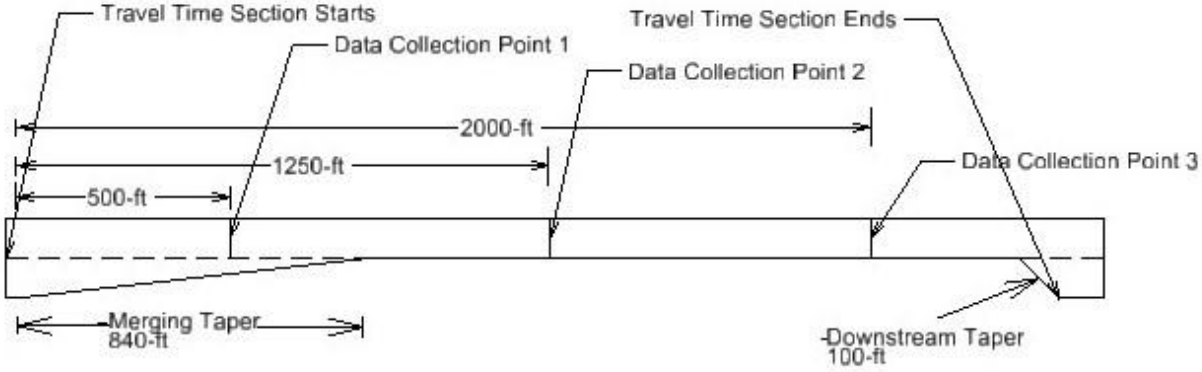


Figure 6 - Layout of Data Collection Points

4.3 DETERMINING THRESHOLD SENSOR OCCUPANCY RATE

In this study, three threshold occupancy rates of the sensors, 20%, 30%, and 40% were investigated to determine the optimal setting of the sensors’ threshold occupancy rate. Therefore, the first step in the statistical analyses of the project is to determine the relationship between the threshold occupancy rate of the sensors and the measures of effectiveness.

To determine the correlation, dummy variables are declared indicating each threshold occupancy rate. For a certain threshold occupancy rate, 1 indicates that the detector threshold occupancy rate is set to that particular occupancy rate, and 0 indicates that it is of any other occupancy rate. To check if there is any correlation between the dummy variables and MOEs, box plots are obtained in the software Statistical Package for the Social Sciences (SPSS). In the x-axis of the box-plot the dummy variable and in the y-axis the respective MOE is plotted. Observing the box-plots, it can be gleaned that a large portion of the values overlap between the two groups of a single dummy variable. In other words, the boxplots obtained from two groups is quite identical in shape. Hence the decision can be taken that there is no correlation between the sensors' threshold occupancy rates and MOEs. The box plot of vehicle throughput and sensors' occupancy rate 20% is provided as a representative example in Figure 4.2. The box plots of other MOEs and threshold occupancy rates were examined, and those were quite similar to this one in shape.

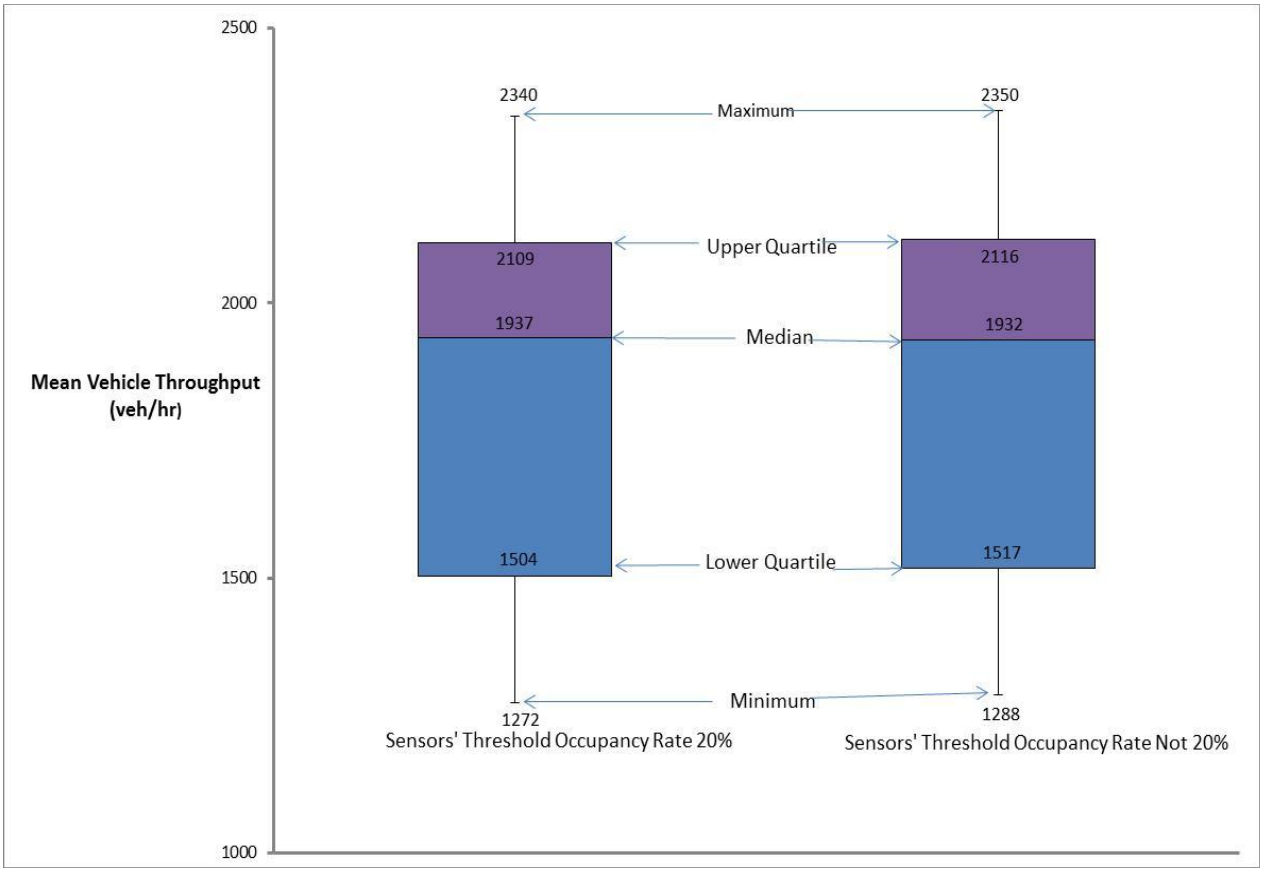


Figure 7 - Correlation between Mean Throughput and 20% Sensors’ Threshold Occupancy Rate

As there is no correlation found between threshold occupancy rates of the sensors’ and MOEs, this variable is excluded from the dataset for further analysis. Initially the simulation of each case consisted of a layout under a certain traffic demand volume was run for three times for each threshold occupancy rate. But as this variable is excluded, the data set can then be merged for all three threshold occupancy rates which increases the total number of simulation runs for each case to nine (instead of three) for each temporary traffic control and traffic volume. In the next phases of the analysis, nine simulation runs were considered for each case.

4.4 COMPARISON BETWEEN CONVENTIONAL MERGE AND DYNAMIC MERGE

A total of twenty five different combinations of temporary traffic controls consisted of both dynamic and conventional merge are investigated in this study. At first a one-way ANOVA is conducted to determine if the values of MOEs under same traffic volume of these temporary traffic control layouts are significantly different from each other at a significance level of 0.05. If values of the MOEs are significantly different from a statistical perspective, then Tukey’s multiple comparison test is conducted to determine the temporary traffic controls whose performance are significantly different than the conventional merge. The detailed output of the Tukey’s multiple comparison tests are attached in Appendix A. In the next section, a coding scheme is used to represent different temporary traffic control layouts for convenience. The codes used for each traffic control layout is provided in Table 6.

Table 6 - Codes used to Represent Temporary Traffic Control Layouts

Type of Merge			Codes
Type of Merge	Number of Signs	Spacing between Signs (Miles)	
Conventional	-	-	CM
Early	1	1/8	EM-1-1/8
Early	1	1/4	EM-1-1/4
Early	1	1/2	EM-1-1/2
Early	2	1/8	EM-2-1/8
Early	2	1/4	EM-2-1/4
Early	2	1/2	EM-2-1/2
Early	3	1/8	EM-3-1/8
Early	3	1/4	EM-3-1/4
Early	3	1/2	EM-3-1/2
Early	4	1/8	EM-4-1/8
Early	4	1/4	EM-4-1/2
Early	4	1/2	EM-4-1/2
Late	1	1/8	LM-1-1/8
Late	1	1/4	LM-1-1/4
Late	1	1/2	LM-1-1/2
Late	2	1/8	LM-2-1/8
Late	2	1/4	LM-2-1/4
Late	2	1/2	LM-2-1/2
Late	3	1/8	LM-3-1/8
Late	3	1/4	LM-3-1/4
Late	3	1/2	LM-3-1/2
Late	4	1/8	LM-4-1/8
Late	4	1/4	LM-4-1/4
Late	4	1/2	LM-4-1/2

A detailed evaluation of the performance under varying traffic conditions of all the temporary traffic controls investigated in this study are provided below:

4.4.1 Traffic volume-1500 vehicles/hour

The null hypothesis of the one-way ANOVA was that the mean throughputs or delays under all layouts of temporary traffic controls are not different from each other statistically at a significance level of 0.05. The alternative hypothesis of the ANOVA was that at least one of the mean vehicle throughputs or delays are not equal to other means statistically. If the p-value obtained after conducting the one-way ANOVA of a certain MOE is below 0.05, then the null hypothesis is rejected and alternative hypothesis is accepted. In Table 4.3, the p-values of both vehicle throughput and delay obtained after running the ANOVA for all truck percentages of 1500 vehicles/hour is provided. When the traffic demand volume is 1500 vehicles/hour, then at 10% truck percentage the null hypothesis is not rejected when the MOE is vehicle throughput. Therefore, there is no statistically significant difference between the mean throughputs produced by the different traffic controls with traffic demand of 1500 vehicles/hour and 10% truck percentage. In the case of 20% and 30% truck percentage, the null hypothesis is rejected. Observing the output of Tukey’s multiple comparison test, it is found that the conventional merge produces the highest vehicle throughput which is statistically significant. The output of Tukey’s multiple comparison test is attached in Appendix A. In the case of delay, the means of delays among different groups are significantly different from each other in all truck percentages, but investigating the output of Tukey’s multiple comparison test; it was obtained that the lowest amount of delay is produced by the conventional merge. Therefore, if the traffic demand volume is 1500 vehicles/hour; with a truck percentage of 10%, 20% or 30%; the conventional merge performs the best in both MOEs of vehicle throughput and delay. In Figures 4.3 and 4.4, the bar charts of the values of vehicle throughput and delay against their respective truck percentages is provided.

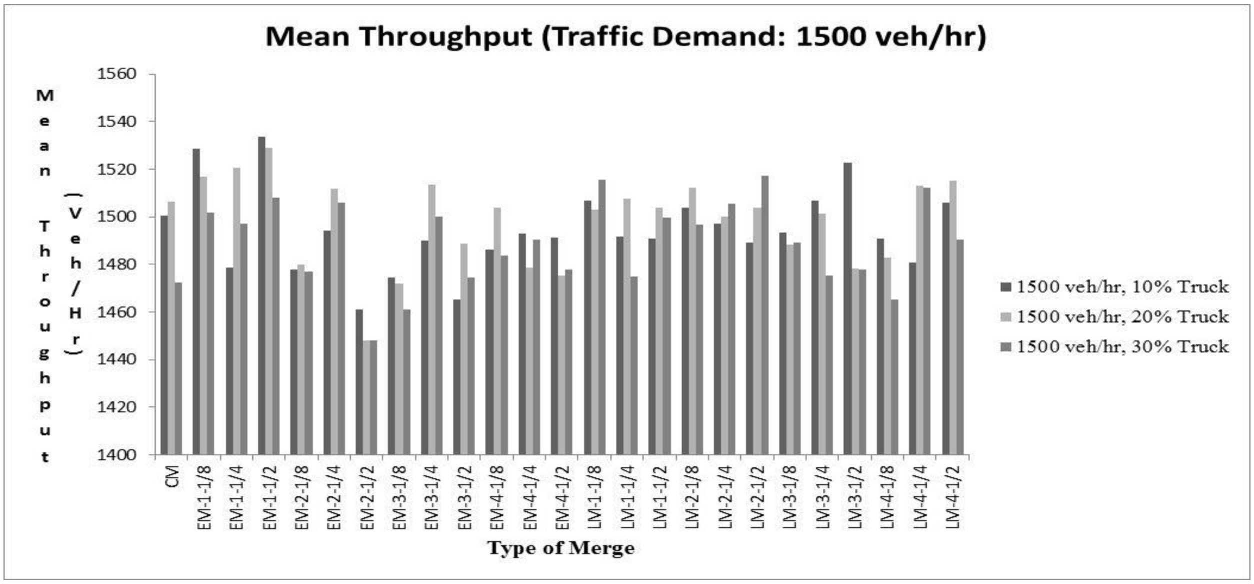


Figure 8 - Mean Vehicle Throughputs when Traffic Demand 1500 vehicles/hour

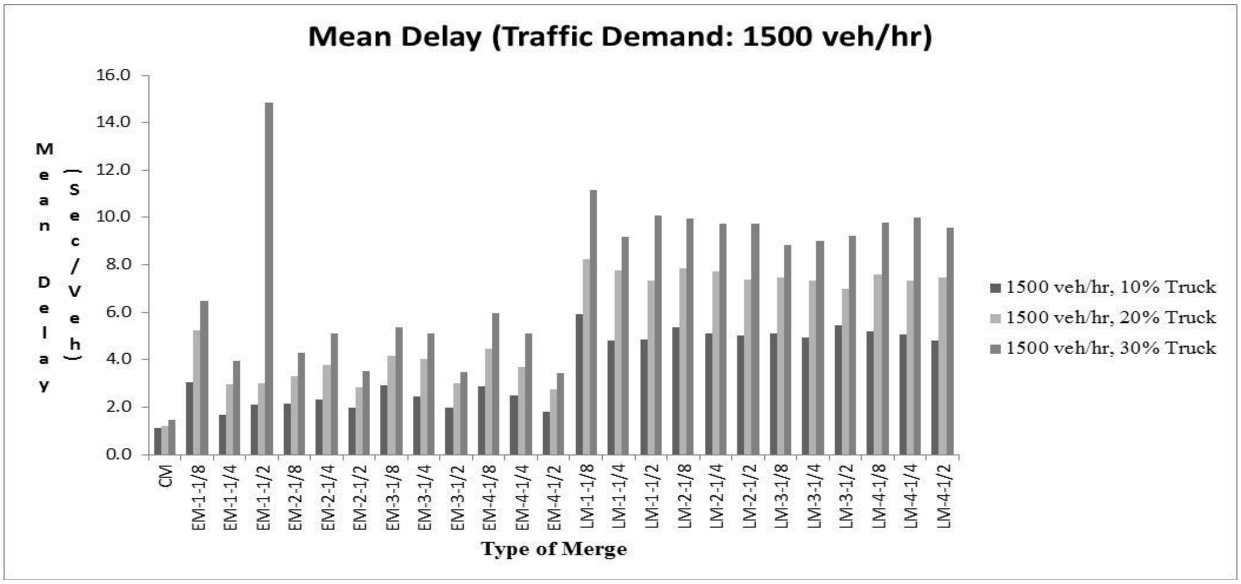


Figure 9 - Mean Delays when Traffic Demand 1500 vehicles/hour

Table 7 - Output of ANOVA when Traffic Volume 1500 vehicles/hour

		Sum of Squares	df	Mean Square	F	Sig.
Vehicle Throughput-1500 veh/hr-10% Truck	Between Groups	45629.788	24	1901.241	1.355	.138
	Within Groups	221757.444	158	1403.528		
	Total	267387.232	182			
Vehicle Throughput-1500 veh/hr-20% Truck	Between Groups	61955.199	24	2581.467	1.850	.014
	Within Groups	220471.722	158	1395.391		
	Total	282426.921	182			
Vehicle Throughput-1500 veh/hr-30% Truck	Between Groups	58485.140	24	2436.881	2.142	.003
	Within Groups	179775.444	158	1137.819		
	Total	238260.585	182			
Delay-1500 veh/hr-10% Truck	Between Groups	391.966	24	16.332	79.747	<.001
	Within Groups	32.358	158	.205		
	Total	424.324	182			
Delay-1500 veh/hr-20% Truck	Between Groups	790.430	24	32.935	73.977	<.001
	Within Groups	70.342	158	.445		
	Total	860.771	182			
Delay-1500 veh/hr-30% Truck	Between Groups	1457.054	24	60.711	11.466	<.001
	Within Groups	836.569	158	5.295		
	Total	2293.623	182			

4.4.2 Traffic Volume 2000 vehicles/hour

In the case of 2000 vehicles/hour, for any percentage of trucks the means of vehicle throughputs and delays of all 25 different traffic controls are statistically not equal. The p-values of each traffic demand volume is presented in Table 4.4. The bar charts of mean vehicle throughput and mean delay are provided in Figures 4.5 and 4.6 respectively. Investigating the output of Tukey's multiple comparison, it is observed that with any truck percentages, the means of throughputs or delays which are statistically different from the conventional merge, are actually less or more respectively compared to the conventional merge. Therefore, if the traffic demand volume is 2000 vehicles/hour, the maintenance of traffic which works best is the conventional merge. The detailed output of Tukey's multiple comparison test is attached to Appendix A.

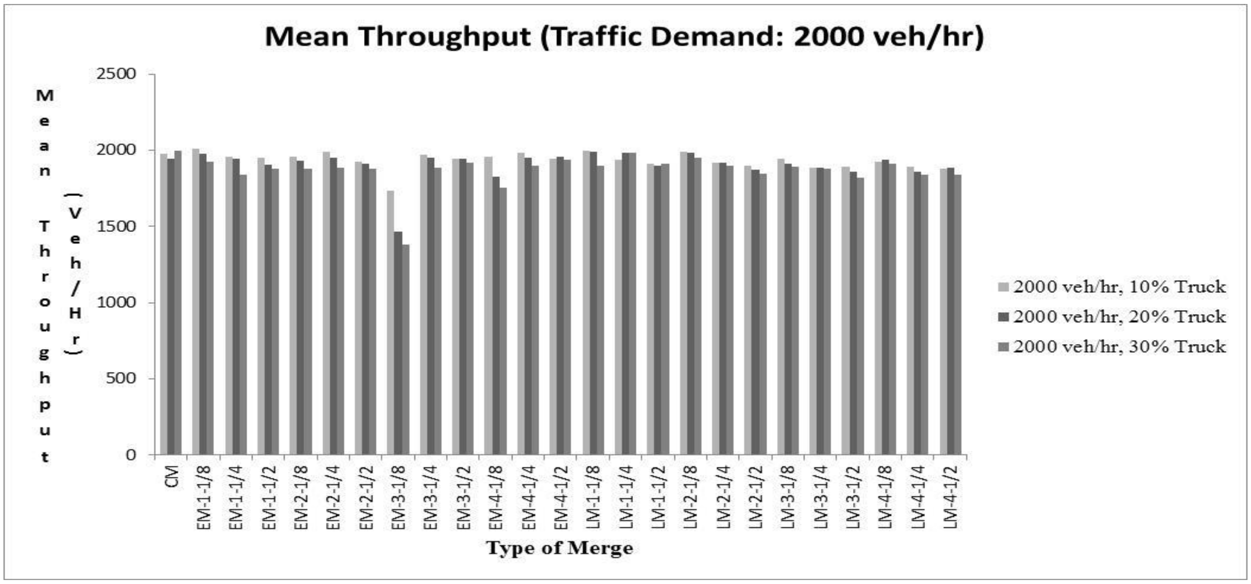


Figure 10 - Mean Vehicle Throughputs when Traffic Demand 2000 vehicles/hour

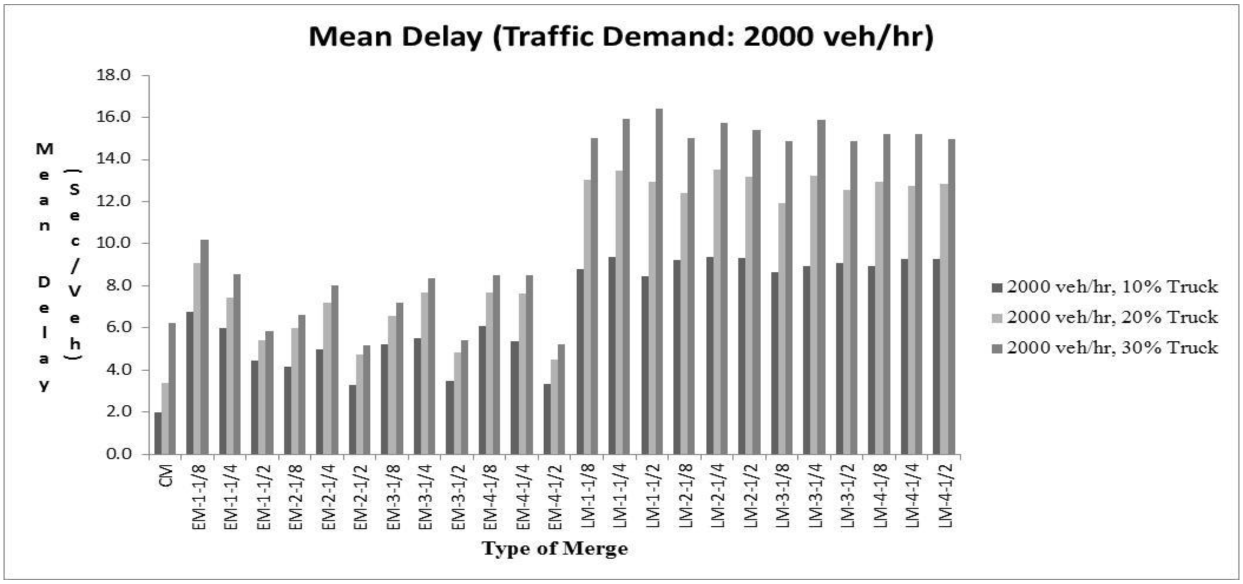


Figure 11 - Mean Delays when Traffic Demand 2000 vehicles/hour

Table 8 - Output of ANOVA when Traffic Demand 2000 vehicles/hour

		Sum of Squares	df	Mean Square	F	Sig.
Vehicle Throughput-2000 veh/hr-10% Truck	Between Groups	577404.196	24	24058.508	10.522	<.001
	Within Groups	361279.722	158	2286.581		
	Total	938683.918	182			
Vehicle Throughput-2000 veh/hr-20% Truck	Between Groups	2074911.077	24	86454.628	24.019	<.001
	Within Groups	568711.778	158	3599.442		
	Total	2643622.855	182			
Vehicle Throughput-2000 veh/hr-30% Truck	Between Groups	2526175.151	24	105257.298	17.552	<.001
	Within Groups	947496.278	158	5996.812		
	Total	3473671.429	182			
Delay-2000 veh/hr-10% Truck	Between Groups	1041.050	24	43.377	79.820	<.001
	Within Groups	85.863	158	.543		
	Total	1126.914	182			
Delay-2000 veh/hr-20% Truck	Between Groups	2160.674	24	90.028	143.441	<.001
	Within Groups	99.166	158	.628		
	Total	2259.839	182			
Delay-2000 veh/hr-30% Truck	Between Groups	3279.420	24	136.643	216.786	<.001
	Within Groups	99.589	158	.630		
	Total	3379.009	182			

4.4.3 Traffic Volume 2500 vehicles/hour

At the volume of 2500 vehicles/hour, when the truck percentage is 10%, the null hypothesis is rejected in both cases of mean vehicle throughput and mean delay. After running the Tukey's multiple comparison test, it is obtained that if vehicle throughput is considered as the MOE then best performance is produced by the conventional merge according to MUTCD. On the other hand, if the performance measure is delay, then delay produced by conventional merge is significantly more (6.8 sec/veh) than the dynamic early merge with three signs with a spacing of 1/8 miles.

When the truck percentage is 20% with 2500 vehicles/hour, the best performance is obtained when the temporary traffic control is the conventional merge if vehicle throughput is the determining criteria. On the other hand, when least delay is the determining criteria, the best performance is provided by the setup of dynamic early merge with four signs with a spacing of a half-mile. The difference between the delay produced by the conventional merge and the recommended traffic control is 8.0 seconds/vehicle.

In the case of traffic demand of 2500 vehicles/hour with truck percentage of 30%, the null hypothesis is rejected for both vehicle throughput and delay. When the performance measure is vehicle throughput the best performing layout is the dynamic late merge with one sign, and the distance between the work zone taper and the sign would be 1/8 miles. In the recommended temporary traffic control, the vehicle throughput is 260 vehicles/hour more than the conventional merge. When delay is considered as the performance measure, the temporary traffic control of the dynamic early merge form with two signs and 1/2 miles spacing produces the least amount of delay which is significant among all other temporary traffic control layouts. The delay produced by the recommended traffic control is 9.1 seconds/vehicle less than the conventional merge.

The output of the ANOVA is presented in Table 4.5 and the output of Tukey's multiple comparison test is attached to Appendix A. The effect of different temporary traffic control layouts against traffic demand volume is presented with the help of bar charts in Figures 4.7 and 4.8 for vehicle throughput and delay respectively.

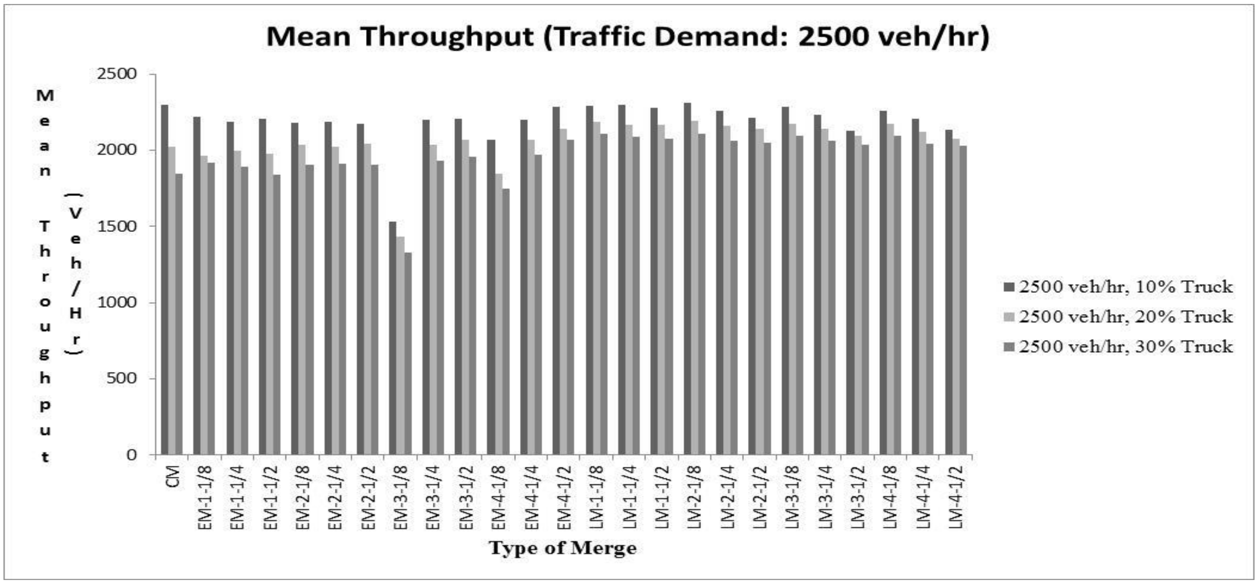


Figure 12 - Mean Vehicle Throughputs when Traffic Demand 2500 vehicles/hour

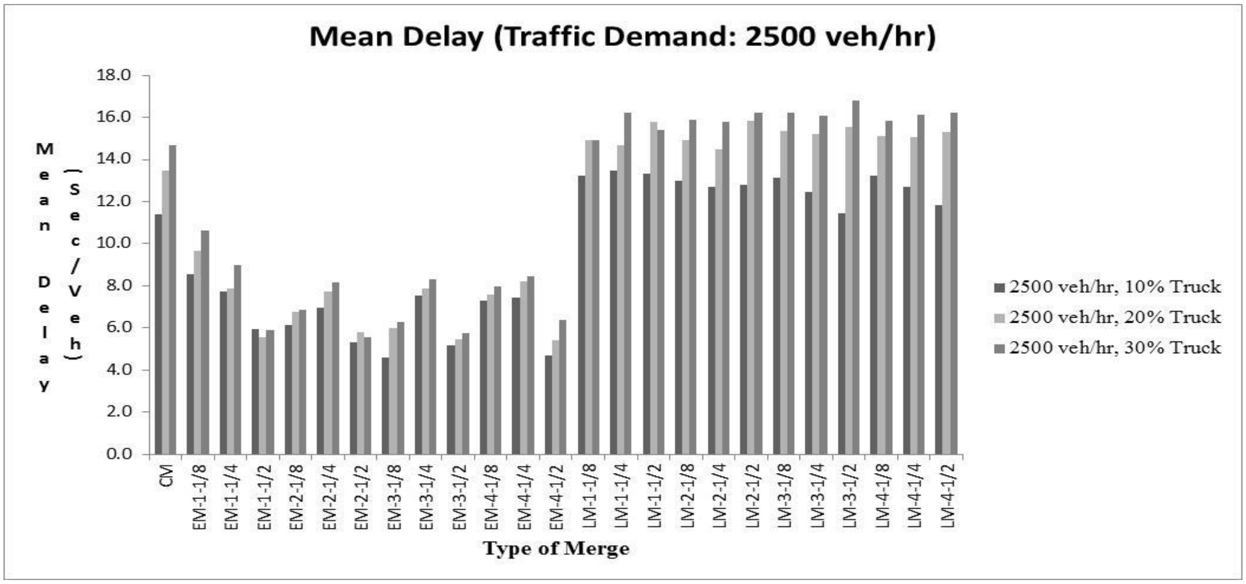


Figure 13 - Mean Delays when Traffic Demand Volume 2500 vehicles/hour

Table 9 - Output of ANOVA when Traffic Volume 2500 vehicles/hour

		Sum of Squares	df	Mean Square	F	Sig.
Vehicle Throughput-2500 veh/hr-10% Truck	Between Groups	4596073.828	24	191503.076	32.815	<.001
	Within Groups	922065.167	158	5835.855		
	Total	5518138.995	182			
Vehicle Throughput-2500 veh/hr-20% Truck	Between Groups	4864950.269	24	202706.261	24.467	<.001
	Within Groups	1308999.611	158	8284.808		
	Total	6173949.880	182			
Vehicle Throughput-2500 veh/hr-30% Truck	Between Groups	5392040.857	24	224668.369	31.169	<.001
	Within Groups	1138868.056	158	7208.026		
	Total	6530908.913	182			
Delay-2500 veh/hr-10% Truck	Between Groups	2018.552	24	84.106	92.458	<.001
	Within Groups	143.728	158	.910		
	Total	2162.280	182			
Delay-2500 veh/hr-20% Truck	Between Groups	3275.132	24	136.464	189.906	<.001
	Within Groups	113.537	158	.719		
	Total	3388.669	182			
Delay-2500 veh/hr-30% Truck	Between Groups	3712.531	24	154.689	222.927	<.001
	Within Groups	109.636	158	.694		
	Total	3822.167	182			

4.4.4 Traffic Volume 3000 vehicles/hour

When the truck percentage is 10% of traffic demand volume of 3000 vehicles/hour, the results of one way ANOVA indicate that for both performance measures vehicle throughput and delay, the null hypothesis is rejected. Therefore, Tukey's multiple comparison test is conducted. It is obtained from the output of the test that conventional merge produces the best output when the performance measure is vehicle throughput. When the performance measure is delay, the dynamic early merge with three signs with a spacing of 1/8 of a mile produces the least amount of delay. The recommended temporary traffic control produces 8.2 seconds/vehicle less delay than conventional merge.

For 20% truck percentage, the conventional merge according to MUTCD performs best when the performance measure is vehicle throughput. On the other hand, when delay is the performance measure, dynamic early merge with four signs and with a spacing of 1/2 of a mile performs the best. It produces a delay of 8.2 seconds/vehicle less than conventional merge.

For 30% truck percentage, when vehicle throughput is the performance measure, the dynamic late merge with two signs and with a spacing of 1/8 of a mile performs the best. It produces an additional 283 vehicles/hour while compared to the vehicle throughput produced by the conventional merge. When delay is considered as the performance measure, dynamic early merge with three signs with a spacing of 1/2 of a mile performs the best. It produces a delay of 8.6 seconds/vehicle less than the conventional merge.

Figures 4.9 and 4.10 show the impact of the different temporary traffic control layouts on the MOEs under the traffic demand volume of 3000 vehicles/hour. Table 4.6 presents the output of the one way ANOVA.

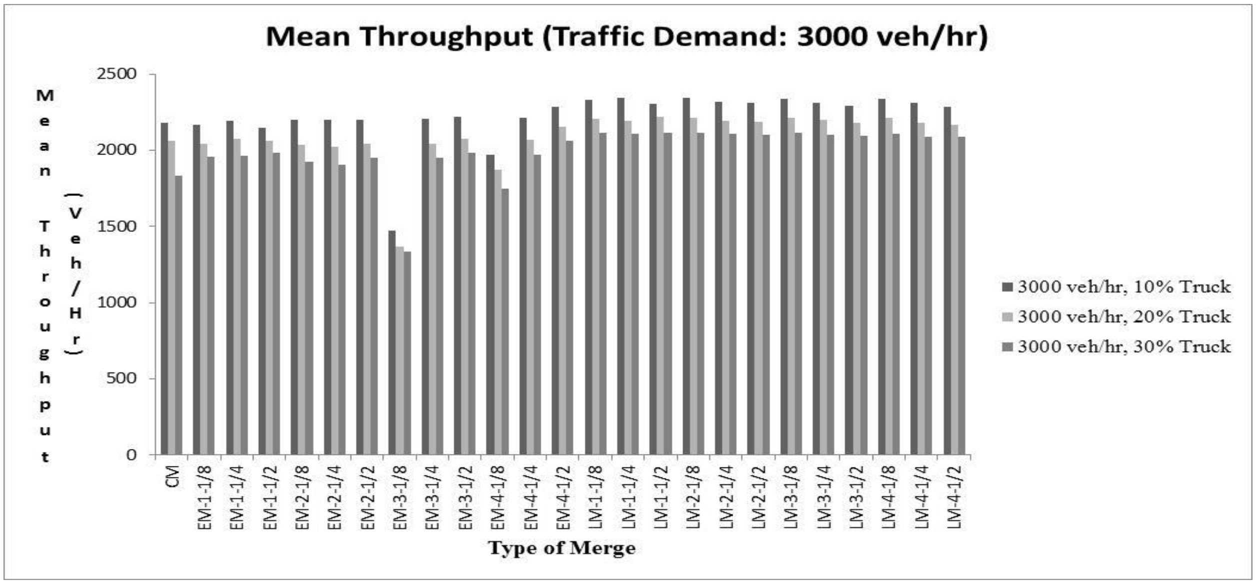


Figure 14 - Mean Vehicle Throughputs when Traffic Demand 3000 vehicles/hour

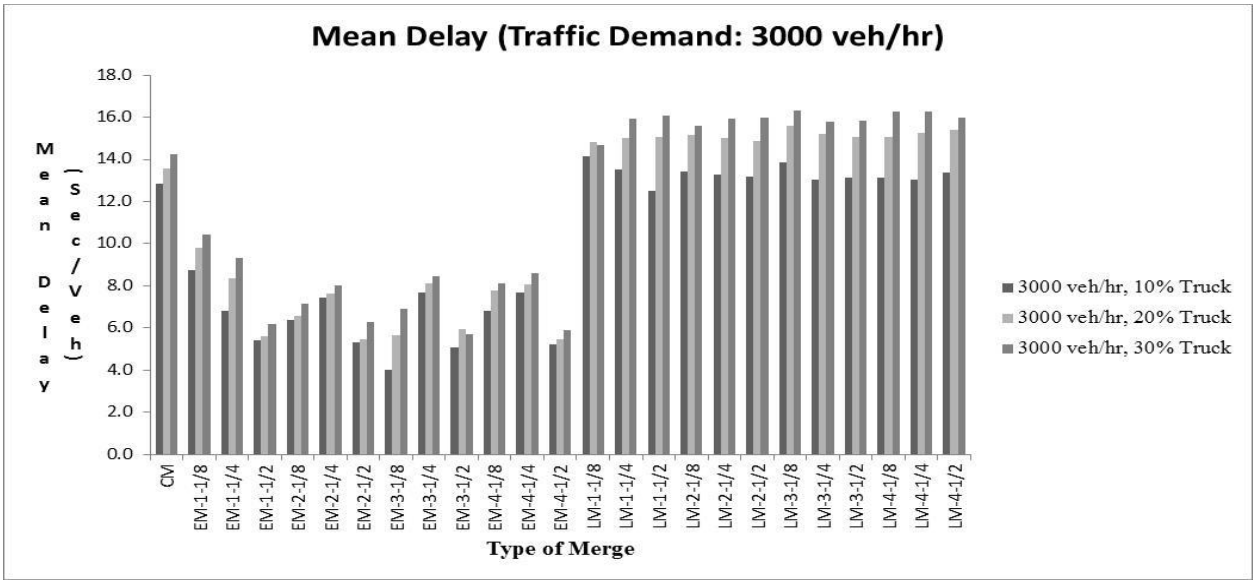


Figure 15 - Mean Delays when Traffic Demand 3000 vehicles/hour

Table 10 - Output of ANOVA when Traffic Volume 3000 vehicles/hour

		Sum of Squares	df	Mean Square	F	Sig.
Vehicle Throughput-3000 veh/hr-10% Truck	Between Groups	6518071.752	24	271586.323	27.793	<.001
	Within Groups	1543934.111	158	9771.735		
	Total	8062005.863	182			
Vehicle Throughput-3000 veh/hr-20% Truck	Between Groups	6280251.177	24	261677.132	34.391	<.001
	Within Groups	1202203.389	158	7608.882		
	Total	7482454.566	182			
Vehicle Throughput-3000 veh/hr-30% Truck	Between Groups	5837704.546	24	243237.689	30.241	<.001
	Within Groups	1270833.556	158	8043.250		
	Total	7108538.101	182			
Delay-3000 veh/hr-10% Truck	Between Groups	2413.578	24	100.566	122.080	<.001
	Within Groups	130.155	158	.824		
	Total	2543.733	182			
Delay-3000 veh/hr-20% Truck	Between Groups	3262.006	24	135.917	205.243	<.001
	Within Groups	104.632	158	.662		
	Total	3366.637	182			
Delay-3000 veh/hr-30% Truck	Between Groups	3469.936	24	144.581	167.527	<.001
	Within Groups	136.358	158	.863		
	Total	3606.294	182			

4.5 SUMMARY OF COMPARISON BETWEEN CONVENTIONAL MERGE AND DYNAMIC MERGE

In the analysis part of the work, the layout which performs statistically better than the rest under a certain scenario is obtained by conducting the one-way ANOVA and corresponding Tukey’s multiple comparison test. In Table 4.7 and 4.8, the temporary traffic control layout which performs statistically best out of all under investigation in this study are provided when the MOEs are vehicle throughput and delay respectively.

Table 11 - Recommended Layout of TTC (Performance Measure: Vehicle Throughput)

Traffic Demand Volume	Truck Percentage	Performance Measure: Vehicle Throughput			
		Recommended Type of Merge	Recommended Number of Signs	Recommended Spacing between Signs	Difference between Recommended merge and conventional merge (vehicles/hour)
1500	10	Conventional	-	-	-
	20	Conventional	-	-	-
	30	Conventional	-	-	-
2000	10	Conventional	-	-	-
	20	Conventional	-	-	-
	30	Conventional	-	-	-
2500	10	Conventional	-	-	-
	20	Conventional	-	-	-
	30	Late Merge	One	1/8	260
3000	10	Conventional	-	-	-
	20	Conventional	-	-	-
	30	Late Merge	Two	1/8	283

Table 12 - Recommended Layout of TTC (Performance Measure: Delay)

Traffic Demand Volume	Truck Percentage	Performance Measure: Delay			
		Recommended Type of Merge	Recommended Number of Signs	Recommended Spacing between Signs	Difference between Recommended merge and conventional merge (seconds/vehicle)
1500	10	Conventional	-	-	
	20	Conventional	-	-	
	30	Conventional	-	-	
2000	10	Conventional	-	-	-
	20	Conventional	-	-	-
	30	Conventional	-	-	-
2500	10	Early Merge	Three	1/8	6.8
	20	Early Merge	Four	1/2	8.0
	30	Early Merge	Two	1/2	9.1
3000	10	Early Merge	Three	1/8	8.2
	20	Early Merge	Four	1/2	8.2
	30	Early Merge	Three	1/2	8.6

4.6 REGRESSION ANALYSIS

The final step in the statistical analysis on the collected data is to conduct a multiple linear regression analysis in which the dependent variable would be any of the measures of effectiveness. Traffic demand volume and truck percentage is the independent variable. In addition to these, dummy variables are declared for all the 24 different layouts of dynamic merge control varying the number of signs and spacing between the signs, and those are included in the model. For instance, if vehicle throughput is the dependent variable, the equation would take the following form:

X_n = 1 if the temporary traffic control n is used (n = 1, 2, 3, ………….., 24)

Vehicle Throughput = $\beta_0 + \beta_{DV}$*(Traffic Demand Volume) + β_{TP}*Truck Percentage + $\sum\beta_n * X_n$

The coefficients of the dummy variables of each of the temporary traffic controls are provided in Table 13 and 14 for vehicle throughput and delay respectively. If the variable is not found to be statistically significant then it does not have any impact on the MOE. On the other hand, if it is found to be statistically significant, then the effect on the MOE can be observed from the value of the regression coefficient. In the result of the regression analysis, it is observed that when the MOE is vehicle throughput most of the temporary traffic controls are not significant. In the case of delay, the scenario is different as most of the temporary traffic controls have statistically significant impact on delay. It is observed that delay is generally less in the case of dynamic early merge, but in the case of dynamic late merge delay is usually higher.

The values of the coefficients of the temporary traffic controls which fall within 95% confidence interval are identified in the tables. The analysis can be conducted by grouping these values together and considering them as one single variable.

Table 13 - Effect of Temporary Traffic Controls on Vehicle Throughput

Coefficients				
Model Parameter	Unstandardized Coefficients		t	Sig.
	β	Std. Error		
(Constant)	1171.771	51.864	22.59	.000
Traffic Demand Volume (veh/hr)	.375	.010	36.89	.000
Truck Percentage	-6.477	.696	-9.30	.000
Early Merge - One Sign - 1/8 miles spacing	7.306	62.804	.11	.907
Early Merge - One Sign - 1/4 miles spacing	-8.306	62.804	-.13	.895
Early Merge - One Sign - 1/2 miles spacing	-10.722	62.804	-.17	.864
Early Merge - Two Signs - 1/8 miles spacing*	**-479.278**	**51.279**	**-9.34**	**.000**
Early Merge - Two Signs - 1/4 miles spacing	-4.407	51.279	-.08	.932
Early Merge - Two Signs - 1/2 miles spacing	-21.546	51.279	-.42	.674
Early Merge - Three Signs - 1/8 miles spacing*	**-431.657**	**51.279**	**-8.41**	**.000**
Early Merge - Three Signs - 1/4 miles spacing	2.491	51.279	.04	.961
Early Merge - Three Signs - 1/2 miles spacing	8.648	51.279	.16	.866
Early Merge - Four Signs - 1/8 miles spacing	-114.120	51.279	-2.22	.026

Early Merge - Four Signs - 1/4 miles spacing	11.407	51.279	.22	.824
Early Merge - Four Signs - 1/2 miles spacing	52.907	51.279	1.03	.303
Late Merge - One Sign - 1/8 miles spacing	**83.472**	**62.804**	**1.32**	**.184**
Late Merge - One Sign - 1/4 miles spacing	**77.972**	**62.804**	**1.24**	**.215**
Late Merge - One Sign - 1/2 miles spacing	**61.278**	**62.804**	**.97**	**.330**
Late Merge - Two Signs - 1/8 miles spacing	**90.259**	**51.279**	**1.76**	**.079**
Late Merge - Two Signs - 1/4 miles spacing	**57.972**	**51.279**	**1.13**	**.259**
Late Merge - Two Signs - 1/2 miles spacing	**40.333**	**51.279**	**.78**	**.432**
Late Merge - Three Signs - 1/8 miles spacing	**66.759**	**51.279**	**1.30**	**.193**
Late Merge - Three Signs - 1/4 miles spacing	**45.250**	**51.279**	**.88**	**.378**
Late Merge - Three Signs - 1/2 miles spacing	19.565	51.279	.38	.703
Late Merge - Four Signs - 1/8 miles spacing	**63.000**	**51.279**	**1.22**	**.220**
Late Merge - Four Signs - 1/4 miles spacing	**33.935**	**51.279**	**.66**	**.508**

Late Merge - Four Signs - 1/2 miles spacing**	**21.000**	**51.279**	**.41**	**.682**

*Values of the coefficients fall within 95% confidence interval of each other

**Values of the coefficients fall within 95% confidence interval of each other

Table 14 - Effect of Temporary Traffic Control on Delay

Coefficients				
	Unstandardized Coefficients		T	Sig.
	β	Std. Error		
(Constant)	-3.024	.579	-5.22	.000
Traffic Demand Volume (veh/hr)	.004	.000	31.04	.000
Truck Percentage	.153	.008	19.68	.000
Early Merge - One Sign - 1/8 miles spacing	.252	.701	.36	.719
Early Merge - One Sign - 1/4 miles spacing	-1.331	.701	-1.89	.058
Early Merge - One Sign - 1/2 miles spacing*	**-2.108**	**.701**	**-3.00**	**.003**
Early Merge - Two Signs - 1/8 miles spacing*	**-1.856**	**.572**	**-3.24**	**.001**
Early Merge - Two Signs - 1/4 miles spacing*	**-1.519**	**.572**	**-2.65**	**.008**
Early Merge - Two Signs - 1/2 miles spacing	-3.355	.572	-5.86	.000
Early Merge - Three Signs - 1/8 miles spacing*	**-2.568**	**.572**	**-4.48**	**.000**

Early Merge - Three Signs - 1/4 miles spacing	-1.210	.572	-2.11	.035
Early Merge - Three Signs - 1/2 miles spacing	-3.367	.572	-5.88	.000
Early Merge - Four Signs - 1/8 miles spacing	-1.208	.572	-2.11	.035
Early Merge - Four Signs - 1/4 miles spacing	-1.193	.572	-2.08	.038
Early Merge - Four Signs - 1/2 miles spacing	-3.463	.572	-6.05	.000
Late Merge - One Sign - 1/8 miles spacing**	**4.436**	**.701**	**6.32**	**.000**
Late Merge - One Sign - 1/4 miles spacing**	**4.481**	**.701**	**6.39**	**.000**
Late Merge - One Sign - 1/2 miles spacing**	**4.383**	**.701**	**6.25**	**.000**
Late Merge - Two Signs - 1/8 miles spacing**	**4.346**	**.572**	**7.59**	**.000**
Late Merge - Two Signs - 1/4 miles spacing**	**4.398**	**.572**	**7.68**	**.000**
Late Merge - Two Signs - 1/2 miles spacing**	**4.443**	**.572**	**7.76**	**.000**
Late Merge - Three Signs - 1/8 miles spacing**	**4.310**	**.572**	**7.53**	**.000**
Late Merge - Three Signs - 1/4 miles spacing**	**4.294**	**.572**	**7.50**	**.000**

Late Merge - Three Signs - 1/2 miles spacing**	**4.205**	**.572**	**7.34**	**.000**
Late Merge - Four Signs - 1/8 miles spacing**	**4.394**	**.572**	**7.67**	**.000**
Late Merge - Four Signs - 1/4 miles spacing**	**4.366**	**.572**	**7.62**	**.000**
Late Merge - Four Signs - 1/2 miles spacing**	**4.288**	**.572**	**7.49**	**.000**

*Values of the coefficients fall within 95% confidence interval of each other

**Values of the coefficients fall within 95% confidence interval of each other

Table 15 – Model Summary (Vehicle Throughput and Delay)

MOE	R	R Square	Adjusted R Square	Std. Error of the Estimate
Vehicle Throughput	0.867	0.752	0.743	153.83812
Delay	0.922	0.850	0.845	1.71710

4.7 CONCLUSION

This chapter provides a detailed description of the different stages of the analysis performed in this research to obtain the findings. Box plots were investigated to obtain an optimal setting of the sensors’ threshold occupancy rates. To obtain an optimal setting of the temporary traffic control under a certain traffic volume, the statistical operation to compare multiple means one-way ANOVA was used. Lastly, to determine the effect of each temporary traffic control on the MOEs, a multiple linear regression analysis was conducted.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The goal of this study was to investigate the effectiveness of dynamic merge control in freeway work zones in a simulated environment. This purpose was served by comparing the performance of dynamic merge control to the performance of a conventional merge according to MUTCD in identical settings. In addition to this, a specific temporary traffic control layout is also suggested under a certain traffic demand, if it is obtained through the analysis that dynamic merge performs significantly better than conventional merge. Moreover, effort was put into obtaining an optimal setting of the sensors' threshold occupancy rate to facilitate the maximum efficiency of the dynamic merge control system.

5.1 FINDINGS OF THE WORK

In the methodology of the research, the simulation models of dynamic merge control and conventional merge are developed in VISSIM. The layout of the dynamic merge control is varied by manipulating the number of dynamic message signs and the spacing between the signs. Then the layouts were tested under different traffic volumes, and sensors' threshold occupancy rates. After the completion of data collection, statistical analysis was performed in SPSS. The major findings of the analysis are following:

- No correlation was found between sensors' threshold occupancy rates and measures of effectiveness. 20%, 30% and 40% sensors' threshold occupancy rates were tested in this study. Lower occupancy rates can be tested in a future study to determine if there is any correlation.
- If the traffic demand volume is less than 2000 vehicles/hour, then irrespective of the truck percentages and measures of effectiveness, conventional merge performs significantly better than dynamic merge control.
- When the measure of effectiveness is vehicle throughput, the dynamic late merge is found to perform significantly better than conventional merge only in the case of high heavy vehicle percentage. Therefore, if the truck percentage is more than 20%, then dynamic late merge is expected to perform better.
- If delay is the determining criterion for the performance and selection of temporary traffic control, then irrespective of the truck percentage, dynamic early merge performs significantly better than dynamic late merge.
- If delay is the determining criterion, then if the traffic volume is higher than 2500 vehicles/hour, dynamic early merge performs significantly better than conventional merge irrespective of the truck percentages.

5.2 RECOMMENDATION FOR FURTHER STUDY

- Throughout this study, drivers' compliance rate is assumed to be 100 percent, which may not be practical. In the future studies on dynamic merge control, the performance can be evaluated by modifying drivers' compliance rate.
- In a future study, sensors' threshold occupancy rate lower than 20% can be investigated to figure if there is any correlation with the measures of effectiveness.

- In this study, a range of one to four dynamic message signs were included in the layouts of temporary traffic controls, and thus the performance was evaluated. In a future study, the number of dynamic message signs can be increased and therefore investigation can be conducted to check if the increase has any positive impact on the performance of the system.
- In this study, the distance between the work zone taper and the first sign upstream is equal to the spacing between the other signs in the system. In future studies, this distance can be varied and increased than the spacing between the remaining signs to figure out if it has any impact on the performance.

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APPENDIX

Output of Tukey's Multiple Comparison Test

Table 15 - Output of Tukey's Multiple Comparison Test of Mean Throughput when Traffic Volume 1500 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-28.000	30.589	1.000	-141.93	85.93
	EM-1-1/4	22.000	30.589	1.000	-91.93	135.93
	EM-1-1/2	-33.000	30.589	1.000	-146.93	80.93
	EM-2-1/8	22.944	24.976	1.000	-70.08	115.97
	EM-2-1/4	6.333	24.976	1.000	-86.69	99.35
	EM-2-1/2	39.556	24.976	.997	-53.47	132.58
	EM-3-1/8	26.000	24.976	1.000	-67.02	119.02
	EM-3-1/4	10.444	24.976	1.000	-82.58	103.47
	EM-3-1/2	35.444	24.976	.999	-57.58	128.47
	EM-4-1/8	14.444	24.976	1.000	-78.58	107.47
	EM-4-1/4	7.778	24.976	1.000	-85.24	100.80
	EM-4-1/2	9.333	24.976	1.000	-83.69	102.35
	LM-1-1/8	-6.000	30.589	1.000	-119.93	107.93
	LM-1-1/4	9.000	30.589	1.000	-104.93	122.93
	LM-1-1/2	10.000	30.589	1.000	-103.93	123.93
	LM-2-1/8	-3.333	24.976	1.000	-96.35	89.69
	LM-2-1/4	3.444	24.976	1.000	-89.58	96.47
	LM-2-1/2	11.667	24.976	1.000	-81.35	104.69
	LM-3-1/8	7.222	24.976	1.000	-85.80	100.24
	LM-3-1/4	-6.333	24.976	1.000	-99.35	86.69
	LM-3-1/2	-22.000	24.976	1.000	-115.02	71.02
	LM-4-1/8	9.889	24.976	1.000	-83.13	102.91
	LM-4-1/4	19.889	24.976	1.000	-73.13	112.91
	LM-4-1/2	-5.222	24.976	1.000	-98.24	87.80

Table 16 - Output of Tukey's Multiple Comparison Test of Mean Throughput when Traffic Volume 1500 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-29.333	27.542	1.000	-131.91	73.24
	EM-1-1/4	-25.000	27.542	1.000	-127.58	77.58
	EM-1-1/2	-35.667	27.542	1.000	-138.24	66.91
	EM-2-1/8	-4.667	22.488	1.000	-88.42	79.09
	EM-2-1/4	-33.667	22.488	.999	-117.42	50.09
	EM-2-1/2	24.333	22.488	1.000	-59.42	108.09
	EM-3-1/8	11.222	22.488	1.000	-72.53	94.98
	EM-3-1/4	-27.778	22.488	1.000	-111.53	55.98
	EM-3-1/2	-2.222	22.488	1.000	-85.98	81.53

	EM-4-1/8	-11.333	22.488	1.000	-95.09	72.42
	EM-4-1/4	-18.222	22.488	1.000	-101.98	65.53
	EM-4-1/2	-5.444	22.488	1.000	-89.20	78.31
	LM-1-1/8	-43.333	27.542	.997	-145.91	59.24
	LM-1-1/4	-2.667	27.542	1.000	-105.24	99.91
	LM-1-1/2	-27.333	27.542	1.000	-129.91	75.24
	LM-2-1/8	-24.222	22.488	1.000	-107.98	59.53
	LM-2-1/4	-33.111	22.488	.999	-116.87	50.64
	LM-2-1/2	-45.111	22.488	.948	-128.87	38.64
	LM-3-1/8	-16.667	22.488	1.000	-100.42	67.09
	LM-3-1/4	-3.000	22.488	1.000	-86.75	80.75
	LM-3-1/2	-5.333	22.488	1.000	-89.09	78.42
	LM-4-1/8	6.889	22.488	1.000	-76.87	90.64
	LM-4-1/4	-40.111	22.488	.986	-123.87	43.64
	LM-4-1/2	-18.111	22.488	1.000	-101.87	65.64

Table 17 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 1500 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-1.90000*	.36950	.000	-3.2762	-.5238
	EM-1-1/4	-.53333	.36950	.999	-1.9095	.8429
	EM-1-1/2	-.96667	.36950	.606	-2.3429	.4095
	EM-2-1/8	-1.01111	.30170	.144	-2.1348	.1125
	EM-2-1/4	-1.17778*	.30170	.028	-2.3014	-.0541
	EM-2-1/2	-.84444	.30170	.465	-1.9681	.2792
	EM-3-1/8	-1.76667*	.30170	.000	-2.8903	-.6430
	EM-3-1/4	-1.32222*	.30170	.005	-2.4459	-.1986
	EM-3-1/2	-.85556	.30170	.437	-1.9792	.2681
	EM-4-1/8	-1.74444*	.30170	.000	-2.8681	-.6208
	EM-4-1/4	-1.36667*	.30170	.003	-2.4903	-.2430
	EM-4-1/2	-.68889	.30170	.835	-1.8125	.4348
	LM-1-1/8	-4.80000*	.36950	.000	-6.1762	-3.4238
	LM-1-1/4	-3.66667*	.36950	.000	-5.0429	-2.2905
	LM-1-1/2	-3.70000*	.36950	.000	-5.0762	-2.3238
	LM-2-1/8	-4.22222*	.30170	.000	-5.3459	-3.0986
	LM-2-1/4	-3.96667*	.30170	.000	-5.0903	-2.8430
	LM-2-1/2	-3.88889*	.30170	.000	-5.0125	-2.7652
	LM-3-1/8	-3.97778*	.30170	.000	-5.1014	-2.8541
	LM-3-1/4	-3.81111*	.30170	.000	-4.9348	-2.6875
	LM-3-1/2	-4.31111*	.30170	.000	-5.4348	-3.1875
	LM-4-1/8	-4.06667*	.30170	.000	-5.1903	-2.9430
	LM-4-1/4	-3.94444*	.30170	.000	-5.0681	-2.8208
	LM-4-1/2	-3.67778*	.30170	.000	-4.8014	-2.5541

Table 18 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 1500 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-4.03333*	.54479	.000	-6.0624	-2.0043
	EM-1-1/4	-1.76667	.54479	.189	-3.7957	.2624
	EM-1-1/2	-1.80000	.54479	.163	-3.8291	.2291
	EM-2-1/8	-2.11111*	.44482	.001	-3.7678	-.4544
	EM-2-1/4	-2.60000*	.44482	.000	-4.2567	-.9433
	EM-2-1/2	-1.62222	.44482	.063	-3.2789	.0345
	EM-3-1/8	-2.97778*	.44482	.000	-4.6345	-1.3211
	EM-3-1/4	-2.84444*	.44482	.000	-4.5012	-1.1877
	EM-3-1/2	-1.78889*	.44482	.019	-3.4456	-.1322
	EM-4-1/8	-3.25556*	.44482	.000	-4.9123	-1.5988
	EM-4-1/4	-2.50000*	.44482	.000	-4.1567	-.8433
	EM-4-1/2	-1.54444	.44482	.105	-3.2012	.1123
	LM-1-1/8	-7.03333*	.54479	.000	-9.0624	-5.0043
	LM-1-1/4	-6.56667*	.54479	.000	-8.5957	-4.5376
	LM-1-1/2	-6.13333*	.54479	.000	-8.1624	-4.1043
	LM-2-1/8	-6.64444*	.44482	.000	-8.3012	-4.9877
	LM-2-1/4	-6.53333*	.44482	.000	-8.1901	-4.8766
	LM-2-1/2	-6.18889*	.44482	.000	-7.8456	-4.5322
	LM-3-1/8	-6.25556*	.44482	.000	-7.9123	-4.5988
	LM-3-1/4	-6.12222*	.44482	.000	-7.7789	-4.4655
	LM-3-1/2	-5.81111*	.44482	.000	-7.4678	-4.1544
	LM-4-1/8	-6.41111*	.44482	.000	-8.0678	-4.7544
	LM-4-1/4	-6.12222*	.44482	.000	-7.7789	-4.4655
	LM-4-1/2	-6.27778*	.44482	.000	-7.9345	-4.6211

Table 19 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 1500 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-5.03333	1.87878	.557	-12.0308	1.9641
	EM-1-1/4	-2.46667	1.87878	1.000	-9.4641	4.5308
	EM-1-1/2	-13.36667*	1.87878	.000	-20.3641	-6.3692
	EM-2-1/8	-2.84444	1.53402	.978	-8.5578	2.8689
	EM-2-1/4	-3.62222	1.53402	.788	-9.3356	2.0912
	EM-2-1/2	-2.06667	1.53402	1.000	-7.7801	3.6467
	EM-3-1/8	-3.91111	1.53402	.657	-9.6245	1.8023
	EM-3-1/4	-3.64444	1.53402	.779	-9.3578	2.0689
	EM-3-1/2	-2.02222	1.53402	1.000	-7.7356	3.6912
	EM-4-1/8	-4.48889	1.53402	.372	-10.2023	1.2245

	EM-4-1/4	-3.65556	1.53402	.774	-9.3689	2.0578
	EM-4-1/2	-1.95556	1.53402	1.000	-7.6689	3.7578
	LM-1-1/8	-9.70000*	1.87878	.000	-16.6974	-2.7026
	LM-1-1/4	-7.73333*	1.87878	.014	-14.7308	-.7359
	LM-1-1/2	-8.60000*	1.87878	.002	-15.5974	-1.6026
	LM-2-1/8	-8.50000*	1.53402	.000	-14.2134	-2.7866
	LM-2-1/4	-8.25556*	1.53402	.000	-13.9689	-2.5422
	LM-2-1/2	-8.26667*	1.53402	.000	-13.9801	-2.5533
	LM-3-1/8	-7.38889*	1.53402	.001	-13.1023	-1.6755
	LM-3-1/4	-7.56667*	1.53402	.001	-13.2801	-1.8533
	LM-3-1/2	-7.76667*	1.53402	.000	-13.4801	-2.0533
	LM-4-1/8	-8.30000*	1.53402	.000	-14.0134	-2.5866
	LM-4-1/4	-8.52222*	1.53402	.000	-14.2356	-2.8088
	LM-4-1/2	-8.10000*	1.53402	.000	-13.8134	-2.3866

Table 20 - Output of Tukey's Multiple Comparison Test of Mean Throughput when Traffic Volume 2000 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-34.000	39.043	1.000	-179.42	111.42
	EM-1-1/4	14.333	39.043	1.000	-131.08	159.75
	EM-1-1/2	22.333	39.043	1.000	-123.08	167.75
	EM-2-1/8	17.278	31.879	1.000	-101.45	136.01
	EM-2-1/4	-16.889	31.879	1.000	-135.62	101.84
	EM-2-1/2	51.444	31.879	.996	-67.29	170.18
	EM-3-1/8	236.778*	31.879	.000	118.05	355.51
	EM-3-1/4	1.333	31.879	1.000	-117.40	120.06
	EM-3-1/2	31.889	31.879	1.000	-86.84	150.62
	EM-4-1/8	16.556	31.879	1.000	-102.18	135.29
	EM-4-1/4	-9.222	31.879	1.000	-127.95	109.51
	EM-4-1/2	31.778	31.879	1.000	-86.95	150.51
	LM-1-1/8	-21.000	39.043	1.000	-166.42	124.42
	LM-1-1/4	34.333	39.043	1.000	-111.08	179.75
	LM-1-1/2	59.667	39.043	.998	-85.75	205.08
	LM-2-1/8	-18.444	31.879	1.000	-137.18	100.29
	LM-2-1/4	57.111	31.879	.985	-61.62	175.84
	LM-2-1/2	73.556	31.879	.821	-45.18	192.29
	LM-3-1/8	32.222	31.879	1.000	-86.51	150.95
	LM-3-1/4	86.778	31.879	.524	-31.95	205.51
	LM-3-1/2	82.333	31.879	.631	-36.40	201.06
	LM-4-1/8	47.444	31.879	.999	-71.29	166.18
	LM-4-1/4	79.556	31.879	.697	-39.18	198.29
	LM-4-1/2	94.444	31.879	.348	-24.29	213.18

Table 21 - Output of Tukey’s Multiple Comparison Test of Mean Throughput when Traffic Volume 2000 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-32.333	48.986	1.000	-214.78	150.11
	EM-1-1/4	2.000	48.986	1.000	-180.45	184.45
	EM-1-1/2	41.000	48.986	1.000	-141.45	223.45
	EM-2-1/8	11.833	39.997	1.000	-137.13	160.80
	EM-2-1/4	-9.889	39.997	1.000	-158.86	139.08
	EM-2-1/2	33.556	39.997	1.000	-115.41	182.52
	EM-3-1/8	479.667*	39.997	.000	330.70	628.63
	EM-3-1/4	-5.778	39.997	1.000	-154.74	143.19
	EM-3-1/2	-1.222	39.997	1.000	-150.19	147.74
	EM-4-1/8	113.778	39.997	.431	-35.19	262.74
	EM-4-1/4	-9.000	39.997	1.000	-157.97	139.97
	EM-4-1/2	-15.889	39.997	1.000	-164.86	133.08
	LM-1-1/8	-45.000	48.986	1.000	-227.45	137.45
	LM-1-1/4	-40.667	48.986	1.000	-223.11	141.78
	LM-1-1/2	42.000	48.986	1.000	-140.45	224.45
	LM-2-1/8	-38.111	39.997	1.000	-187.08	110.86
	LM-2-1/4	24.556	39.997	1.000	-124.41	173.52
	LM-2-1/2	72.111	39.997	.984	-76.86	221.08
	LM-3-1/8	30.444	39.997	1.000	-118.52	179.41
	LM-3-1/4	55.667	39.997	1.000	-93.30	204.63
	LM-3-1/2	86.222	39.997	.897	-62.74	235.19
	LM-4-1/8	7.222	39.997	1.000	-141.74	156.19
	LM-4-1/4	81.556	39.997	.939	-67.41	230.52
	LM-4-1/2	55.778	39.997	1.000	-93.19	204.74

Table 22 - Output of Tukey’s Multiple Comparison Test of Mean Throughput when Traffic Volume 2000 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	71.000	63.229	1.000	-164.49	306.49
	EM-1-1/4	159.000	63.229	.683	-76.49	394.49
	EM-1-1/2	117.667	63.229	.977	-117.83	353.16
	EM-2-1/8	115.111	51.626	.863	-77.17	307.39
	EM-2-1/4	109.667	51.626	.910	-82.61	301.95
	EM-2-1/2	120.556	51.626	.804	-71.72	312.83
	EM-3-1/8	612.444*	51.626	.000	420.17	804.72
	EM-3-1/4	107.889	51.626	.922	-84.39	300.17
	EM-3-1/2	79.889	51.626	.998	-112.39	272.17
	EM-4-1/8	240.778*	51.626	.002	48.50	433.06
	EM-4-1/4	98.222	51.626	.970	-94.06	290.50
	EM-4-1/2	59.222	51.626	1.000	-133.06	251.50
	LM-1-1/8	100.667	63.229	.997	-134.83	336.16

	LM-1-1/4	15.333	63.229	1.000	-220.16	250.83
	LM-1-1/2	83.667	63.229	1.000	-151.83	319.16
	LM-2-1/8	45.556	51.626	1.000	-146.72	237.83
	LM-2-1/4	96.444	51.626	.976	-95.83	288.72
	LM-2-1/2	151.222	51.626	.370	-41.06	343.50
	LM-3-1/8	101.444	51.626	.958	-90.83	293.72
	LM-3-1/4	117.556	51.626	.838	-74.72	309.83
	LM-3-1/2	174.000	51.626	.138	-18.28	366.28
	LM-4-1/8	87.111	51.626	.993	-105.17	279.39
	LM-4-1/4	157.667	51.626	.289	-34.61	349.95
	LM-4-1/2	154.000	51.626	.334	-38.28	346.28

Table 23 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2000 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-4.76667*	.60191	.000	-7.0084	-2.5249
	EM-1-1/4	-4.00000*	.60191	.000	-6.2418	-1.7582
	EM-1-1/2	-2.46667*	.60191	.014	-4.7084	-.2249
	EM-2-1/8	-2.13333*	.49146	.006	-3.9637	-.3029
	EM-2-1/4	-2.97778*	.49146	.000	-4.8082	-1.1474
	EM-2-1/2	-1.28889	.49146	.601	-3.1193	.5415
	EM-3-1/8	-3.20000*	.49146	.000	-5.0304	-1.3696
	EM-3-1/4	-3.50000*	.49146	.000	-5.3304	-1.6696
	EM-3-1/2	-1.48889	.49146	.304	-3.3193	.3415
	EM-4-1/8	-4.10000*	.49146	.000	-5.9304	-2.2696
	EM-4-1/4	-3.37778*	.49146	.000	-5.2082	-1.5474
	EM-4-1/2	-1.31111	.49146	.566	-3.1415	.5193
	LM-1-1/8	-6.76667*	.60191	.000	-9.0084	-4.5249
	LM-1-1/4	-7.36667*	.60191	.000	-9.6084	-5.1249
	LM-1-1/2	-6.43333*	.60191	.000	-8.6751	-4.1916
	LM-2-1/8	-7.21111*	.49146	.000	-9.0415	-5.3807
	LM-2-1/4	-7.35556*	.49146	.000	-9.1860	-5.5252
	LM-2-1/2	-7.33333*	.49146	.000	-9.1637	-5.5029
	LM-3-1/8	-6.64444*	.49146	.000	-8.4748	-4.8140
	LM-3-1/4	-6.94444*	.49146	.000	-8.7748	-5.1140
	LM-3-1/2	-7.08889*	.49146	.000	-8.9193	-5.2585
	LM-4-1/8	-6.93333*	.49146	.000	-8.7637	-5.1029
	LM-4-1/4	-7.28889*	.49146	.000	-9.1193	-5.4585
	LM-4-1/2	-7.28889*	.49146	.000	-9.1193	-5.4585

Table 24 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2000 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-5.73333*	.64685	.000	-8.1425	-3.3242
	EM-1-1/4	-4.06667*	.64685	.000	-6.4758	-1.6575
	EM-1-1/2	-2.06667	.64685	.212	-4.4758	.3425
	EM-2-1/8	-2.60556*	.52815	.001	-4.5726	-.6385
	EM-2-1/4	-3.83333*	.52815	.000	-5.8004	-1.8662
	EM-2-1/2	-1.37778	.52815	.611	-3.3449	.5893
	EM-3-1/8	-3.17778*	.52815	.000	-5.1449	-1.2107
	EM-3-1/4	-4.30000*	.52815	.000	-6.2671	-2.3329
	EM-3-1/2	-1.44444	.52815	.514	-3.4115	.5226
	EM-4-1/8	-4.31111*	.52815	.000	-6.2782	-2.3440
	EM-4-1/4	-4.26667*	.52815	.000	-6.2338	-2.2996
	EM-4-1/2	-1.11111	.52815	.917	-3.0782	.8560
	LM-1-1/8	-9.66667*	.64685	.000	-12.0758	-7.2575
	LM-1-1/4	-10.10000*	.64685	.000	-12.5092	-7.6908
	LM-1-1/2	-9.56667*	.64685	.000	-11.9758	-7.1575
	LM-2-1/8	-9.02222*	.52815	.000	-10.9893	-7.0551
	LM-2-1/4	-10.16667*	.52815	.000	-12.1338	-8.1996
	LM-2-1/2	-9.80000*	.52815	.000	-11.7671	-7.8329
	LM-3-1/8	-8.57778*	.52815	.000	-10.5449	-6.6107
	LM-3-1/4	-9.87778*	.52815	.000	-11.8449	-7.9107
	LM-3-1/2	-9.16667*	.52815	.000	-11.1338	-7.1996
	LM-4-1/8	-9.58889*	.52815	.000	-11.5560	-7.6218
	LM-4-1/4	-9.36667*	.52815	.000	-11.3338	-7.3996
	LM-4-1/2	-9.46667*	.52815	.000	-11.4338	-7.4996

Table 25 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2000 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-3.96667*	.64823	.000	-6.3810	-1.5524
	EM-1-1/4	-2.30000	.64823	.085	-4.7143	.1143
	EM-1-1/2	.36667	.64823	1.000	-2.0476	2.7810
	EM-2-1/8	-.37778	.52928	1.000	-2.3491	1.5935
	EM-2-1/4	-1.80000	.52928	.127	-3.7713	.1713
	EM-2-1/2	1.04444	.52928	.956	-.9268	3.0157
	EM-3-1/8	-.95556	.52928	.984	-2.9268	1.0157
	EM-3-1/4	-2.10000*	.52928	.023	-4.0713	-.1287
	EM-3-1/2	.82222	.52928	.998	-1.1491	2.7935
	EM-4-1/8	-2.25556*	.52928	.008	-4.2268	-.2843

	EM-4-1/4	-2.28889*	.52928	.006	-4.2602	-.3176
	EM-4-1/2	1.03333	.52928	.961	-.9379	3.0046
	LM-1-1/8	-8.76667*	.64823	.000	-11.1810	-6.3524
	LM-1-1/4	-9.70000*	.64823	.000	-12.1143	-7.2857
	LM-1-1/2	-10.20000*	.64823	.000	-12.6143	-7.7857
	LM-2-1/8	-8.78889*	.52928	.000	-10.7602	-6.8176
	LM-2-1/4	-9.48889*	.52928	.000	-11.4602	-7.5176
	LM-2-1/2	-9.14444*	.52928	.000	-11.1157	-7.1732
	LM-3-1/8	-8.62222*	.52928	.000	-10.5935	-6.6509
	LM-3-1/4	-9.64444*	.52928	.000	-11.6157	-7.6732
	LM-3-1/2	-8.63333*	.52928	.000	-10.6046	-6.6621
	LM-4-1/8	-8.96667*	.52928	.000	-10.9379	-6.9954
	LM-4-1/4	-8.95556*	.52928	.000	-10.9268	-6.9843
	LM-4-1/2	-8.71111*	.52928	.000	-10.6824	-6.7398

Table 26 - Output of Tukey’s Multiple Comparison Test of Mean Vehicle Throughput when Traffic Volume 2500 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	75.333	62.374	1.000	-156.98	307.64
	EM-1-1/4	109.667	62.374	.988	-122.64	341.98
	EM-1-1/2	89.667	62.374	.999	-142.64	321.98
	EM-2-1/8	115.278	50.929	.845	-74.40	304.96
	EM-2-1/4	108.889	50.929	.904	-80.79	298.57
	EM-2-1/2	121.667	50.929	.771	-68.01	311.35
	EM-3-1/8	763.778*	50.929	.000	574.10	953.46
	EM-3-1/4	100.889	50.929	.954	-88.79	290.57
	EM-3-1/2	92.333	50.929	.983	-97.35	282.01
	EM-4-1/8	229.667*	50.929	.003	39.99	419.35
	EM-4-1/4	100.222	50.929	.957	-89.46	289.90
	EM-4-1/2	13.889	50.929	1.000	-175.79	203.57
	LM-1-1/8	9.333	62.374	1.000	-222.98	241.64
	LM-1-1/4	-2.667	62.374	1.000	-234.98	229.64
	LM-1-1/2	22.000	62.374	1.000	-210.31	254.31
	LM-2-1/8	-15.778	50.929	1.000	-205.46	173.90
	LM-2-1/4	40.889	50.929	1.000	-148.79	230.57
	LM-2-1/2	83.111	50.929	.996	-106.57	272.79
	LM-3-1/8	10.222	50.929	1.000	-179.46	199.90
	LM-3-1/4	66.222	50.929	1.000	-123.46	255.90
	LM-3-1/2	169.000	50.929	.157	-20.68	358.68
	LM-4-1/8	37.111	50.929	1.000	-152.57	226.79
	LM-4-1/4	91.000	50.929	.986	-98.68	280.68
	LM-4-1/2	166.333	50.929	.179	-23.35	356.01

Table 27 - Output of Tukey’s Multiple Comparison Test of Mean Vehicle Throughput when Traffic Volume 2500 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	59.333	74.318	1.000	-217.46	336.13
	EM-1-1/4	27.667	74.318	1.000	-249.13	304.46
	EM-1-1/2	49.667	74.318	1.000	-227.13	326.46
	EM-2-1/8	-9.389	60.681	1.000	-235.39	216.61
	EM-2-1/4	.444	60.681	1.000	-225.56	226.45
	EM-2-1/2	-19.222	60.681	1.000	-245.22	206.78
	EM-3-1/8	591.667*	60.681	.000	365.66	817.67
	EM-3-1/4	-10.333	60.681	1.000	-236.34	215.67
	EM-3-1/2	-47.000	60.681	1.000	-273.00	179.00
	EM-4-1/8	175.444	60.681	.397	-50.56	401.45
	EM-4-1/4	-46.111	60.681	1.000	-272.11	179.89
	EM-4-1/2	-120.000	60.681	.955	-346.00	106.00
	LM-1-1/8	-164.333	74.318	.872	-441.13	112.46
	LM-1-1/4	-142.333	74.318	.968	-419.13	134.46
	LM-1-1/2	-143.000	74.318	.966	-419.80	133.80
	LM-2-1/8	-166.778	60.681	.503	-392.78	59.22
	LM-2-1/4	-134.111	60.681	.872	-360.11	91.89
	LM-2-1/2	-115.444	60.681	.970	-341.45	110.56
	LM-3-1/8	-150.333	60.681	.710	-376.34	75.67
	LM-3-1/4	-119.444	60.681	.957	-345.45	106.56
	LM-3-1/2	-72.111	60.681	1.000	-298.11	153.89
	LM-4-1/8	-151.667	60.681	.694	-377.67	74.34
	LM-4-1/4	-96.667	60.681	.997	-322.67	129.34
	LM-4-1/2	-50.556	60.681	1.000	-276.56	175.45

Table 28 - Output of Tukey’s Multiple Comparison Test of Mean Vehicle Throughput when Traffic Volume 2500 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-70.333	69.321	1.000	-328.52	187.85
	EM-1-1/4	-45.000	69.321	1.000	-303.18	213.18
	EM-1-1/2	10.000	69.321	1.000	-248.18	268.18
	EM-2-1/8	-60.167	56.600	1.000	-270.97	150.64
	EM-2-1/4	-60.556	56.600	1.000	-271.36	150.25
	EM-2-1/2	-59.778	56.600	1.000	-270.58	151.03
	EM-3-1/8	522.111*	56.600	.000	311.31	732.92
	EM-3-1/4	-84.889	56.600	.999	-295.69	125.92
	EM-3-1/2	-110.111	56.600	.962	-320.92	100.69
	EM-4-1/8	99.333	56.600	.989	-111.47	310.14

	EM-4-1/4	-120.222	56.600	.910	-331.03	90.58
	EM-4-1/2	-218.889*	56.600	.032	-429.69	-8.08
	LM-1-1/8	-260.333*	69.321	.045	-518.52	-2.15
	LM-1-1/4	-240.667	69.321	.105	-498.85	17.52
	LM-1-1/2	-228.667	69.321	.165	-486.85	29.52
	LM-2-1/8	-260.222*	56.600	.002	-471.03	-49.42
	LM-2-1/4	-215.222*	56.600	.039	-426.03	-4.42
	LM-2-1/2	-201.222	56.600	.083	-412.03	9.58
	LM-3-1/8	-246.222*	56.600	.006	-457.03	-35.42
	LM-3-1/4	-213.222*	56.600	.044	-424.03	-2.42
	LM-3-1/2	-185.444	56.600	.174	-396.25	25.36
	LM-4-1/8	-244.556*	56.600	.006	-455.36	-33.75
	LM-4-1/4	-194.444	56.600	.116	-405.25	16.36
	LM-4-1/2	-182.111	56.600	.201	-392.92	28.69

Table 29 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2500 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	2.86667	.77875	.057	-.0337	5.7671
	EM-1-1/4	3.66667*	.77875	.001	.7663	6.5671
	EM-1-1/2	5.46667*	.77875	.000	2.5663	8.3671
	EM-2-1/8	5.26111*	.63584	.000	2.8929	7.6293
	EM-2-1/4	4.44444*	.63584	.000	2.0763	6.8126
	EM-2-1/2	6.07778*	.63584	.000	3.7096	8.4460
	EM-3-1/8	6.82222*	.63584	.000	4.4540	9.1904
	EM-3-1/4	3.85556*	.63584	.000	1.4874	6.2237
	EM-3-1/2	6.23333*	.63584	.000	3.8652	8.6015
	EM-4-1/8	4.12222*	.63584	.000	1.7540	6.4904
	EM-4-1/4	3.97778*	.63584	.000	1.6096	6.3460
	EM-4-1/2	6.70000*	.63584	.000	4.3318	9.0682
	LM-1-1/8	-1.83333	.77875	.793	-4.7337	1.0671
	LM-1-1/4	-2.06667	.77875	.577	-4.9671	.8337
	LM-1-1/2	-1.93333	.77875	.706	-4.8337	.9671
	LM-2-1/8	-1.56667	.63584	.719	-3.9348	.8015
	LM-2-1/4	-1.28889	.63584	.942	-3.6571	1.0793
	LM-2-1/2	-1.37778	.63584	.892	-3.7460	.9904
	LM-3-1/8	-1.74444	.63584	.507	-4.1126	.6237
	LM-3-1/4	-1.07778	.63584	.993	-3.4460	1.2904
	LM-3-1/2	-.05556	.63584	1.000	-2.4237	2.3126
	LM-4-1/8	-1.83333	.63584	.403	-4.2015	.5348
	LM-4-1/4	-1.28889	.63584	.942	-3.6571	1.0793
	LM-4-1/2	-.41111	.63584	1.000	-2.7793	1.9571

Table 30 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2500 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	3.80000*	.69214	.000	1.2222	6.3778
	EM-1-1/4	5.60000*	.69214	.000	3.0222	8.1778
	EM-1-1/2	7.90000*	.69214	.000	5.3222	10.4778
	EM-2-1/8	6.69444*	.56513	.000	4.5896	8.7992
	EM-2-1/4	5.73333*	.56513	.000	3.6285	7.8381
	EM-2-1/2	7.65556*	.56513	.000	5.5508	9.7604
	EM-3-1/8	7.45556*	.56513	.000	5.3508	9.5604
	EM-3-1/4	5.57778*	.56513	.000	3.4730	7.6826
	EM-3-1/2	8.00000*	.56513	.000	5.8952	10.1048
	EM-4-1/8	5.87778*	.56513	.000	3.7730	7.9826
	EM-4-1/4	5.26667*	.56513	.000	3.1619	7.3715
	EM-4-1/2	8.03333*	.56513	.000	5.9285	10.1381
	LM-1-1/8	-1.43333	.69214	.929	-4.0112	1.1445
	LM-1-1/4	-1.20000	.69214	.990	-3.7778	1.3778
	LM-1-1/2	-2.33333	.69214	.137	-4.9112	.2445
	LM-2-1/8	-1.45556	.56513	.637	-3.5604	.6492
	LM-2-1/4	-1.00000	.56513	.987	-3.1048	1.1048
	LM-2-1/2	-2.38889*	.56513	.009	-4.4937	-.2841
	LM-3-1/8	-1.87778	.56513	.155	-3.9826	.2270
	LM-3-1/4	-1.73333	.56513	.281	-3.8381	.3715
	LM-3-1/2	-2.08889	.56513	.055	-4.1937	.0159
	LM-4-1/8	-1.62222	.56513	.412	-3.7270	.4826
	LM-4-1/4	-1.57778	.56513	.470	-3.6826	.5270
	LM-4-1/2	-1.84444	.56513	.180	-3.9492	.2604

Table 31 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 2500 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	4.06667*	.68015	.000	1.5335	6.5998
	EM-1-1/4	5.73333*	.68015	.000	3.2002	8.2665
	EM-1-1/2	8.80000*	.68015	.000	6.2668	11.3332
	EM-2-1/8	7.84444*	.55534	.000	5.7761	9.9128
	EM-2-1/4	6.55556*	.55534	.000	4.4872	8.6239
	EM-2-1/2	9.13333*	.55534	.000	7.0650	11.2017
	EM-3-1/8	8.44444*	.55534	.000	6.3761	10.5128
	EM-3-1/4	6.40000*	.55534	.000	4.3317	8.4683
	EM-3-1/2	8.96667*	.55534	.000	6.8983	11.0350
	EM-4-1/8	6.73333*	.55534	.000	4.6650	8.8017

	EM-4-1/4	6.24444*	.55534	.000	4.1761	8.3128
	EM-4-1/2	8.33333*	.55534	.000	6.2650	10.4017
	LM-1-1/8	-.20000	.68015	1.000	-2.7332	2.3332
	LM-1-1/4	-1.53333	.68015	.850	-4.0665	.9998
	LM-1-1/2	-.70000	.68015	1.000	-3.2332	1.8332
	LM-2-1/8	-1.16667	.55534	.918	-3.2350	.9017
	LM-2-1/4	-1.10000	.55534	.954	-3.1683	.9683
	LM-2-1/2	-1.51111	.55534	.524	-3.5794	.5572
	LM-3-1/8	-1.50000	.55534	.540	-3.5683	.5683
	LM-3-1/4	-1.36667	.55534	.721	-3.4350	.7017
	LM-3-1/2	-2.12222*	.55534	.037	-4.1906	-.0539
	LM-4-1/8	-1.15556	.55534	.925	-3.2239	.9128
	LM-4-1/4	-1.40000	.55534	.678	-3.4683	.6683
	LM-4-1/2	-1.52222	.55534	.509	-3.5906	.5461

Table 32 - Output of Tukey's Multiple Comparison Test of Mean Throughput when Traffic Volume 3000 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	17.667	80.712	1.000	-282.94	318.28
	EM-1-1/4	-7.000	80.712	1.000	-307.61	293.61
	EM-1-1/2	36.667	80.712	1.000	-263.94	337.28
	EM-2-1/8	-15.444	65.901	1.000	-260.89	230.00
	EM-2-1/4	-13.778	65.901	1.000	-259.22	231.67
	EM-2-1/2	-17.111	65.901	1.000	-262.56	228.34
	EM-3-1/8	707.556*	65.901	.000	462.11	953.00
	EM-3-1/4	-20.667	65.901	1.000	-266.11	224.78
	EM-3-1/2	-38.333	65.901	1.000	-283.78	207.11
	EM-4-1/8	212.000	65.901	.201	-33.45	457.45
	EM-4-1/4	-26.889	65.901	1.000	-272.34	218.56
	EM-4-1/2	-102.667	65.901	.998	-348.11	142.78
	LM-1-1/8	-150.667	80.712	.976	-451.28	149.94
	LM-1-1/4	-160.333	80.712	.953	-460.94	140.28
	LM-1-1/2	-122.333	80.712	.998	-422.94	178.28
	LM-2-1/8	-162.889	65.901	.714	-408.34	82.56
	LM-2-1/4	-132.444	65.901	.947	-377.89	113.00
	LM-2-1/2	-125.667	65.901	.969	-371.11	119.78
	LM-3-1/8	-157.000	65.901	.775	-402.45	88.45
	LM-3-1/4	-130.000	65.901	.956	-375.45	115.45
	LM-3-1/2	-110.222	65.901	.994	-355.67	135.22
	LM-4-1/8	-152.889	65.901	.814	-398.34	92.56
	LM-4-1/4	-129.111	65.901	.959	-374.56	116.34
	LM-4-1/2	-99.111	65.901	.999	-344.56	146.34

Table 33 - Output of Tukey’s Multiple Comparison Test of Mean Throughput when Traffic Volume 3000 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	17.000	71.222	1.000	-248.26	282.26
	EM-1-1/4	-13.333	71.222	1.000	-278.60	251.93
	EM-1-1/2	3.000	71.222	1.000	-262.26	268.26
	EM-2-1/8	29.444	58.153	1.000	-187.14	246.03
	EM-2-1/4	40.333	58.153	1.000	-176.25	256.92
	EM-2-1/2	18.556	58.153	1.000	-198.03	235.14
	EM-3-1/8	694.444*	58.153	.000	477.86	911.03
	EM-3-1/4	20.556	58.153	1.000	-196.03	237.14
	EM-3-1/2	-14.556	58.153	1.000	-231.14	202.03
	EM-4-1/8	187.556	58.153	.197	-29.03	404.14
	EM-4-1/4	-7.556	58.153	1.000	-224.14	209.03
	EM-4-1/2	-92.778	58.153	.997	-309.36	123.81
	LM-1-1/8	-142.333	71.222	.950	-407.60	122.93
	LM-1-1/4	-130.000	71.222	.981	-395.26	135.26
	LM-1-1/2	-154.000	71.222	.894	-419.26	111.26
	LM-2-1/8	-150.000	58.153	.634	-366.59	66.59
	LM-2-1/4	-132.778	58.153	.835	-349.36	83.81
	LM-2-1/2	-122.333	58.153	.917	-338.92	94.25
	LM-3-1/8	-148.222	58.153	.657	-364.81	68.36
	LM-3-1/4	-136.667	58.153	.795	-353.25	79.92
	LM-3-1/2	-119.333	58.153	.935	-335.92	97.25
	LM-4-1/8	-151.556	58.153	.613	-368.14	65.03
	LM-4-1/4	-115.889	58.153	.951	-332.48	100.70
	LM-4-1/2	-105.889	58.153	.982	-322.48	110.70

Table 34 - Output of Tukey’s Multiple Comparison Test of Mean Throughput when Traffic Volume 3000 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	-123.333	73.227	.993	-396.06	149.40
	EM-1-1/4	-130.333	73.227	.986	-403.06	142.40
	EM-1-1/2	-150.000	73.227	.936	-422.73	122.73
	EM-2-1/8	-92.944	59.789	.998	-315.63	129.74
	EM-2-1/4	-72.667	59.789	1.000	-295.35	150.02
	EM-2-1/2	-113.222	59.789	.972	-335.91	109.46
	EM-3-1/8	500.000*	59.789	.000	277.32	722.68
	EM-3-1/4	-114.222	59.789	.969	-336.91	108.46
	EM-3-1/2	-147.333	59.789	.719	-370.02	75.35
	EM-4-1/8	88.556	59.789	.999	-134.13	311.24

	EM-4-1/4	-133.333	59.789	.863	-356.02	89.35
	EM-4-1/2	-224.556*	59.789	.045	-447.24	-1.87
	LM-1-1/8	-282.000*	73.227	.033	-554.73	-9.27
	LM-1-1/4	-273.667*	73.227	.048	-546.40	-.94
	LM-1-1/2	-280.000*	73.227	.037	-552.73	-7.27
	LM-2-1/8	-282.778*	59.789	.001	-505.46	-60.09
	LM-2-1/4	-276.556*	59.789	.002	-499.24	-53.87
	LM-2-1/2	-268.556*	59.789	.003	-491.24	-45.87
	LM-3-1/8	-282.333*	59.789	.001	-505.02	-59.65
	LM-3-1/4	-265.444*	59.789	.004	-488.13	-42.76
	LM-3-1/2	-259.778*	59.789	.006	-482.46	-37.09
	LM-4-1/8	-274.444*	59.789	.002	-497.13	-51.76
	LM-4-1/4	-254.111*	59.789	.008	-476.79	-31.43
	LM-4-1/2	-252.889*	59.789	.009	-475.57	-30.21

Table 35 - Output of Tukey's Multiple Comparison Test of Mean Delay when Traffic Volume 3000 Vehicles/hour and Truck Percentage 10%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	4.10000*	.74106	.000	1.3399	6.8601
	EM-1-1/4	6.00000*	.74106	.000	3.2399	8.7601
	EM-1-1/2	7.43333*	.74106	.000	4.6733	10.1934
	EM-2-1/8	6.43889*	.60508	.000	4.1853	8.6925
	EM-2-1/4	5.37778*	.60508	.000	3.1242	7.6314
	EM-2-1/2	7.50000*	.60508	.000	5.2464	9.7536
	EM-3-1/8	8.82222*	.60508	.000	6.5686	11.0758
	EM-3-1/4	5.14444*	.60508	.000	2.8909	7.3980
	EM-3-1/2	7.77778*	.60508	.000	5.5242	10.0314
	EM-4-1/8	6.02222*	.60508	.000	3.7686	8.2758
	EM-4-1/4	5.16667*	.60508	.000	2.9131	7.4202
	EM-4-1/2	7.63333*	.60508	.000	5.3798	9.8869
	LM-1-1/8	-1.33333	.74106	.984	-4.0934	1.4267
	LM-1-1/4	-.70000	.74106	1.000	-3.4601	2.0601
	LM-1-1/2	.33333	.74106	1.000	-2.4267	3.0934
	LM-2-1/8	-.61111	.60508	1.000	-2.8647	1.6425
	LM-2-1/4	-.46667	.60508	1.000	-2.7202	1.7869
	LM-2-1/2	-.36667	.60508	1.000	-2.6202	1.8869
	LM-3-1/8	-1.02222	.60508	.993	-3.2758	1.2314
	LM-3-1/4	-.21111	.60508	1.000	-2.4647	2.0425
	LM-3-1/2	-.32222	.60508	1.000	-2.5758	1.9314
	LM-4-1/8	-.31111	.60508	1.000	-2.5647	1.9425
	LM-4-1/4	-.21111	.60508	1.000	-2.4647	2.0425
	LM-4-1/2	-.53333	.60508	1.000	-2.7869	1.7202

Table 36 - Output of Tukey’s Multiple Comparison Test of Mean Delay when Traffic Volume 3000 Vehicles/hour and Truck Percentage 20%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	3.76667*	.66444	.000	1.2920	6.2414
	EM-1-1/4	5.20000*	.66444	.000	2.7253	7.6747
	EM-1-1/2	7.96667*	.66444	.000	5.4920	10.4414
	EM-2-1/8	7.00556*	.54252	.000	4.9850	9.0261
	EM-2-1/4	5.92222*	.54252	.000	3.9016	7.9428
	EM-2-1/2	8.08889*	.54252	.000	6.0683	10.1095
	EM-3-1/8	7.92222*	.54252	.000	5.9016	9.9428
	EM-3-1/4	5.45556*	.54252	.000	3.4350	7.4761
	EM-3-1/2	7.64444*	.54252	.000	5.6239	9.6650
	EM-4-1/8	5.78889*	.54252	.000	3.7683	7.8095
	EM-4-1/4	5.48889*	.54252	.000	3.4683	7.5095
	EM-4-1/2	8.11111*	.54252	.000	6.0905	10.1317
	LM-1-1/8	-1.23333	.66444	.977	-3.7080	1.2414
	LM-1-1/4	-1.43333	.66444	.896	-3.9080	1.0414
	LM-1-1/2	-1.50000	.66444	.849	-3.9747	.9747
	LM-2-1/8	-1.60000	.54252	.357	-3.6206	.4206
	LM-2-1/4	-1.45556	.54252	.554	-3.4761	.5650
	LM-2-1/2	-1.31111	.54252	.752	-3.3317	.7095
	LM-3-1/8	-2.03333*	.54252	.046	-4.0539	-.0128
	LM-3-1/4	-1.63333	.54252	.316	-3.6539	.3872
	LM-3-1/2	-1.51111	.54252	.475	-3.5317	.5095
	LM-4-1/8	-1.51111	.54252	.475	-3.5317	.5095
	LM-4-1/4	-1.67778	.54252	.267	-3.6984	.3428
	LM-4-1/2	-1.85556	.54252	.121	-3.8761	.1650

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Table 37 - Output of Tukey’s Multiple Comparison Test of Mean Delay when Traffic Volume 3000 Vehicles/hour and Truck Percentage 30%

(I) Type of Merge	(J) Type of Merge	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CM	EM-1-1/8	3.80000*	.75852	.000	.9749	6.6251
	EM-1-1/4	4.90000*	.75852	.000	2.0749	7.7251
	EM-1-1/2	8.03333*	.75852	.000	5.2083	10.8584
	EM-2-1/8	7.08333*	.61933	.000	4.7767	9.3900
	EM-2-1/4	6.21111*	.61933	.000	3.9044	8.5178
	EM-2-1/2	7.95556*	.61933	.000	5.6489	10.2622
	EM-3-1/8	7.33333*	.61933	.000	5.0267	9.6400
	EM-3-1/4	5.80000*	.61933	.000	3.4933	8.1067
	EM-3-1/2	8.55556*	.61933	.000	6.2489	10.8622
	EM-4-1/8	6.11111*	.61933	.000	3.8044	8.4178

	EM-4-1/4	5.62222*	.61933	.000	3.3156	7.9289
	EM-4-1/2	8.32222*	.61933	.000	6.0156	10.6289
	LM-1-1/8	-.46667	.75852	1.000	-3.2917	2.3584
	LM-1-1/4	-1.70000	.75852	.857	-4.5251	1.1251
	LM-1-1/2	-1.83333	.75852	.752	-4.6584	.9917
	LM-2-1/8	-1.36667	.61933	.874	-3.6733	.9400
	LM-2-1/4	-1.70000	.61933	.506	-4.0067	.6067
	LM-2-1/2	-1.73333	.61933	.465	-4.0400	.5733
	LM-3-1/8	-2.07778	.61933	.143	-4.3844	.2289
	LM-3-1/4	-1.53333	.61933	.711	-3.8400	.7733
	LM-3-1/2	-1.57778	.61933	.658	-3.8844	.7289
	LM-4-1/8	-2.02222	.61933	.179	-4.3289	.2844
	LM-4-1/4	-2.03333	.61933	.172	-4.3400	.2733
	LM-4-1/2	-1.76667	.61933	.425	-4.0733	.5400