SAFETY EVALUATION OF WORK ZONE INCLUDING ITS TECHNOLOGIES USING STOCHASTIC MICRO-SIMULATION

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ABSTRACT

In recent years, there has been a considerable increase in the amount of construction work on the U.S. national highways, resulting in lane closure in work zone area, causing congestion with a high traffic demand. The congestion increases number and severity of traffic conflicts which raises the potential for accidents; furthermore traffic operational properties of roadway in work zone area become worse. ITS-based technology such as dynamic lane merging and variable speed limits were adopted by several states to enhance both safety and mobility of roadway work zones. Dynamic lane merging (DLM) in its two main forms namely the early merge and the late merge was designed to advise drivers on definite merging locations. Variable speed limits (VSL) were introduced to work zones to decrease speed fluctuations and to smoothen traffic through work zones. Up to date, there are no studies that contrast standalone or a combination of ITS technologies to standard work zones under matching conditions.
work zone settings. This study simulates a two-to-one work zone lane closure configuration in VISSIM under six different Maintenance of Traffic (MOT) plans. The first MOT consisted of the conventional plans used in Florida work zones, the second MOT consisted of a simplified dynamic early merging system (early SDLMS), the third MOT consisted of a simplified dynamic late merging systems (late SDLMS), the fourth MOT consisted appending a VSL to the conventional Florida MOT, the fifth MOT consisted of adding a VSL to the early SDLMS, and the sixth MOT consisted of adding a VSL to the late SDLMS. From the safety point of view, early and late SDLMS performed poorly as compared to VSL and Motorist Awareness System (MAS) when higher volumes were involved, but the addition of VSL improved their safety aspect by decreasing the speed variance of the vehicles traveling in both open and a closed lane. It was concluded that the passage of traffic through a work zone is made safer when a speed control is integrated to a dynamic merge system.

1 INTRODUCTION
To improve traffic safety and mobility in work zone areas, several states of the U.S. explored the DLM systems and VSL. The DLM systems are intelligent work zone traffic control systems that respond to real-time traffic changes via traffic sensors. The DLM systems are designed to advise drivers on definite merging locations and can take two forms; dynamic early merge and dynamic late merge. The idea behind the dynamic early merge is to create a dynamic no-passing zone to encourage drivers to merge into the open lane before reaching the end of a queue and to prohibit them from using the closed lane to pass vehicles in the queue and merge into the open lane ahead of them (Tarko and Venugopal, 2001). The concept behind late merge is to make more efficient use of roadway storage space by allowing drivers to use all available traffic lanes to the merge point. Once the merge point is reached, the drivers in each lane take turns proceeding through the work zone (Beacher et al., 2004).

Several studies were undertaken to contrast the early form of the DLM (Tarko and Venugopal, 2001, Tarko et al., 1998, McCoy et al, 1999) or the late form of the DLM (Beacher et al., 2004, McCoy and Pesti, 2006, Meyer, 2004, URS Report, 2003 & 2004, Grillo et al, 2008) to existing Maintenance of Traffic (MOT) plans or standard MUTCD work zone traffic control plans. Whereas each study exposes the advantages and disadvantages of the tested systems, up to date there are no studies that cross compares both merging schemes (i.e. early and late DLM) under the same work zone settings.

VSL systems are a type of ITS-technology that involves the setting of maximum and or minimum speed limits. They display speed limits based on observed real time traffic and or weather conditions. Moreover, speed limits that are perceived to be unreasonably low can lead to low speed-limit compliance rates, and high variance in vehicle speeds. With VSL, the hypothesis is that motorists will respond better to realistic speed limits, resulting in higher compliance, and lower speed variance (Lyles et al, 2004).

Our research team at the University of Central Florida in accordance with the Florida Department of Transportation (FDOT) incorporated an ITS-based lane management system, namely the DLM system, into the Florida conventional MOT plans known as the Motorist Awareness System (MAS) (FDOT Plans Preparation Manual). Two resulting modified MAS plans for two-to-one work zone lane closure configuration, identified as the Simplified Dynamic Lane Merging Systems (SDLMS) were designed and deployed in the field. The first
SDLMS is a simplified dynamic early merging system (early SDLMS) and the second system is a simplified dynamic late merging system (late SDLMS) (Harb et al., 2009). Details about the DLM systems are provided in following sections. Field data collection was limited to two days under each MOT type; therefore, recommendations were restricted to the observed field conditions. To expand on the findings and to test the suggested systems under different vehicular and driver characteristics, microscopic simulation is used in this study.

There exist a wide range of tools to evaluate the safety and mobility of drivers at work zone lane closures. QUEWZ, QuickZone, and DELAY Enhanced 1.2 are analytical tools developed to assess traffic impacts at work zones. However, these tools in addition to the methodology presented by HCM 2000 do not offer the flexibility of adjusting for the lane management strategy (DLM) and assigning variable speeds as suggested in this study. VISSIM is microscopic stochastic simulation package that enables creating specific scenarios (e.g. DLM and VSL logic) via vehicle actuated programming (VAP). A program reflecting our algorithm (DLM and VSL logic) was coded to communicate with VISSIM in real-time. The next sections introduce VISSIM and elaborate on the methodology followed in simulating the dynamic lane merging in VISSIM.

The objective of this research is to compare amongst the early and late SDLMSs and the conventional MAS used in Florida, all in the presence of VSL to identify the safety effectiveness of each MOT plan and to make recommendations on the implementation of the suggested systems. The objective is to restrict freeway work zones consisting of a two-to-one lane closure configuration. This study simulates a two-to-one work zone lane closure configuration in VISSIM under six different Maintenance of Traffic (MOT) plans. The first MOT consisted of the conventional plans used in Florida work zones, the second MOT consisted of a simplified dynamic early merging system (early SDLMS), the third MOT consisted of a simplified dynamic late merging systems (late SDLMS), the fourth MOT consisted appending a VSL to the conventional Florida MOT, the fifth MOT consisted of adding a VSL to the early SDLMS, and the sixth MOT consisted of adding a VSL to the late SDLMS. The effectiveness of each MOT type is determined for different levels of drivers’ adherence to the messages displayed by the systems, different levels of truck percentages in the traffic composition, and different levels of demand volumes.

The remainder of this paper is organized as follows. Brief description of all the six scenarios, VISSIM simulation including network coding and VAP coding to mimic both VSL and SDLMS logic, field data collection, calibration and validation of the simulation models. Finally, scenario runs with different levels of drivers’ compliance, truck percentages, and demand volumes are presented, followed by conclusions and recommendations.

2 SCENARIO DESCRIPTION

2.1 Motorist Awareness System (MAS)
Currently, the Florida Department of Transportation (FDOT) deploys an MOT plan known as the Motorist Awareness System (MAS). According to the Florida Plans Preparation Manual (PPM), the MAS consists of Portable Regulatory Signs (PRS) highlighting regulatory speed for the work zone and a Radar Speed Display Unit (RSDU) displaying motorist’s work zone speed. The MAS also comprises a Portable Changeable Message Sign (PCMS), a lane drop
warning sign, a speeding fines doubled warning sign, in addition to road work ahead warning signs (FDOT Plans Preparation Manual).

2.2 Early / Late SDLMS and VSL

The early and late SDLMSs consist of supplementing conventional MAS plans with one Portable Changeable Message Sign (PCMS) and a non-intrusive sensor (Remote Traffic Microwave Sensor, RTMS) trailer as shown in Figure 1. The messages displayed by the PCMS define whether the system is an early or late SDLMS. For VSL operations, PRS (used in MAS) is replaced by a PCMS that displayed the average speed over every 2-minute time interval. It should be noted here that the location of both additional PCMSs and the sensor trailer are identical for all VSL, early and late SDLMS combinations.

The SDLMS operates under two modes; the passive mode and the active mode. Under passive mode, additional PCMS is set to display a flashing “CAUTION/CAUTION” message for both early and late SDLMS. Under active mode, the PCMS displays “DO NOT PASS” followed by “MERGE HERE” alternately for early SDLMS and “STAY IN YOUR LANE” followed by “MERGE AHEAD” alternately for late SDLMS. The early and late SDLMS are activated once average speed over any 2-minute time interval drops below 50mph. The SDLMS will be deactivated (passive mode) once average speed over the next time stamp goes over 50 mph. It should also be noted that the minimum activation time of the PCMS was set for 5 minutes.

Similarly, the speed of vehicles at advance warning area is calculated during a cycle time of 2-minutes and the corresponding average speed distribution is posted at the VSL in the increments of 5mph. If the average speed drop is more than 5 mph, the VSL will display the reduced speed i.e., 5 miles less than the previously posted speed until the average speed goes beyond the posted speed.

Figure 1 MAS Plans and Modifications
3 VISSIM SIMULATION

VISSIM is a microscopic, time step and behavior based simulation model. VISSIM is a commercially available traffic simulation package developed by PTV AG, Karlsruhe, Germany, and distributed in the United States by PTV America, Inc. (VISSIM 4.3, 2007).

The work zone with a 2-to-1 lane closure configuration can be built in VISSIM through a series of links, connectors, routing decisions and lane closures to represent the actual geometry of a work zone. Figure 2 shows the Modified MOT plans for the 2-to-1 lane closure and the corresponding resulting nodes and roadway segments in VISSIM on the actual scale and dimensions. The roadway is drawn on top of the image with links and connectors. Figure 2 shows 6 links and 5 nodes. The first node represents first work zone PCMS. The second node represents the location of VSL whereas node 3 shows the location of additional PCMS where merging information is provided to drivers. Node 4 represents the lane closure start (one open lane). Node 5 represents the lane closure end (two lanes open).

The next step was to mimic the VSL and SDLMS logic in VISSIM. Recalling the SDLMS algorithm applied in the field, first the RTMS captures the speed of vehicles over two-minute time intervals and the built-in algorithm checks if the speed threshold is reached. If the speed threshold is reached, additional PCMS displays the necessary messages. The PCMS keeps displaying the messages until another speed threshold is reached. When early SDLMS message is displayed, drivers merge to the open lane. When late SDLMS message is displayed, drivers stay in their lane until the taper. Similarly, the speed of vehicles at advance warning area is calculated during a cycle time of 2-minutes and the corresponding average speed distribution is posted at the VSL in the increments of 5 mph. If the average speed drop is more than 5 mph, the VSL will display the reduced speed i.e., 5 miles less than the previously posted speed until the average speed goes beyond the posted speed.

![Figure 2: Modified MOT Plan Replication in VISSIM](image)

To imitate early SDLMS in VISSIM, partial decision routing were designated. Drivers either follow a decision routing designated to merge early (when speed drops below threshold) or follow a random merging (when speed remains above speed threshold). For instance in Figure 3, the striped region is designated as partial route 1 (PCMS activated, early merge instructions) and the solid color region is designated as partial route 2 (PCMS not activated, random merging). The alternation between partial route 1 (early merge/PCMS activated) and partial route 2 (PCMS not activated, random merging) was controlled by the
VAP. Two loop detectors were placed (in VISSIM) at the same location on which RTMS was placed in the field. The loop detectors in VISSIM capture individual vehicles' speed. These loop detectors can communicate with signal controllers and can only interact with traffic signals. Since, loop detectors cannot directly communicate with the routing decision, Vehicle Actuated Programming (VAP) is used. VAP “is an optional add-on to VISSIM for the simulation of programmable, phase or stage based, traffic actuated signal controls. The control logic is coded in a *.txt file format and the VAP interpret the control logic commands and creates commands for the VISSIM network. At the same time various detectors variables reflecting the current traffic situation are retrieved from the simulation and processed in the logic” (VISSIM 4.3, 2007). The same logic was followed for coding late SDLMS in VISSIM. However, three partial routes were created. Partial routes 2 and 3 for late merge and partial route 1 for random merging. As for the MAS, there was no need for partial routes, only one static routing decision was created.

For VSL algorithm, two loop detectors have been introduced in the advance warning area (in VISSIM model) to calculate speed for the VSL. Drivers continue to merge randomly in this case with these reduced speeds displayed. These loop detectors can communicate with signal controllers and can only interact with traffic signals. Since, loop detectors cannot directly communicate with the desired speed decision, VAP is used for this case too. Two desired speed decision points are placed in each lane 4,780 feet (0.9 miles) upstream of the taper. These desired speed decision points served as VSL with their posted speed changes in accordance with the VAP logic. These desired speed decision points are placed at the same location where PRS sign was placed. The VSL only scenario is similar to MAS with respect to routing decisions but differs only in exclusive desired speed decision points that act as VSL. Initially sensors for speed detection were placed 1,000 ft upstream of the taper but after a few simulation runs, it was found that VSL is not much effective. It was observed that vehicles tend to decrease speed once they reach close to the taper. For that reason, sensors were placed near the start of taper in both lanes. Integrated SDLMS with VSL scenarios are similar to their respective merge strategy except the addition of VSL logic and added desired speed decision points. Figure 3 illustrates VSL desired speed decision points for both early and late SDLMS+VSL combinations.

An important factor in SDLMS is the driver’s compliance rate to messages displayed by the PCMS. To reflect compliance rate in simulation model and since partial routing decision can control specific vehicle classes, Four vehicle classes are created; Obey-Car, Obey-Truck, Disobey-Car and Disobey-Truck. Obey-Car and Obey-Truck vehicle classes represent vehicles that are controlled by partial routing decision therefore complying with the PCMS messages. The Disobey-Car and Disobey-Truck are not controlled by partial routing decision constituting the non-complying vehicles. The traffic composition was set to contain all 4 vehicle classes and it was modified manually to reflect different levels of compliance.
4 FIELD DATA COLLECTION
The selected site was located on Interstate-95 in Malabar, Florida. I-95 is 2-lane per direction limited access rural freeway with 70mph speed limit (reduced to 60mph during work). The work zone consisted of a resurfacing and milling job on south bound of I-95 on a 13 mile stretch. A 2-to-1 lane closure configuration was adopted and the work zone moved on a daily basis covering a length of approximately 3 miles per day. Data was collected on homogenous basic freeway segment of I-95 with no on/off ramps (Harb et al., 2010).

5 CALIBRATION AND VALIDATION OF THE VISSIM MODEL
The VISSIM simulation model used for this study was calibrated for SDLMS previously at CATSS (University of Central Florida) (Harb et al., 2010). The calibration process that was adopted is briefly described hereunder;

Travel time through work zone was chosen as index of comparison. Secondly, required number of simulation runs was established. Then an initial evaluation was conducted with VISSIM’s driving behavior’s default parameters. An examination of the key parameters was conducted and calibration parameters were determined. Multiple runs with different values of the key parameters were run by trial and error until the calibration was completed. Finally, for the model validation, the work zone throughput (different data-set) was used to verify the homogeneity between the real and simulated environment.

The above mentioned calibrated model was then validated. The validation of the VISSIM work zone model consisted of several parts. First, early SDLMS was validated using throughput at the onset of congestion as the Measure of Effectiveness (MOE). Second, late SDLMS was validated with the same driving behavior parameter sets using travel time and throughput at the onset of congestion as MOEs. Third, the MAS was validated with the same driving behavior parameter sets using throughput at the onset of congestion as a MOE. From
calibration process, runs that resulted in an acceptable p-values (>0.05) and acceptable errors (<5%) were used for the validation process. For each validation run 10 iterations with different seed numbers were completed and the resulting throughputs were collected (Harb et al., 2010).

6 SIMULATION AND RESULTS

Objective of this simulation study is to determine the safety effectiveness of SDLMS systems under VSL operation under different drivers’ compliance rate, different truck percentage in traffic composition, and different traffic demand volumes. Since crashes are rarely observed in the field, surrogate measures such as speed variance and speed difference between lead and following vehicles are often used to quantify safety. In this study, a surrogate speed variance is taken as measure of safety (Kang, 2006). Speed variance reduction indirectly contributes in improving overall traffic safety in work zones (Kang et al., 2004).

Four different levels of drivers’ compliance rate, C20, C40, C60, C80 (each depicting 20%, 40%, 60% or 80% compliance of drivers with the merging instruction, respectively) are created. Three different levels of truck percentage in the traffic composition are created, T10, T20 and T30 (trucks constitute 10%, 20% or 30% of the demand volume). Five different traffic demand volume levels are created. V0500 means traffic demand volume is 500 vph, V1000 means traffic demand volume is 1000 vph, V1500 means traffic demand volume is 1500 vph, V2000 means traffic demand volume is 2000 vph and V2500 means traffic demand volume is 2500 vph. Having 4 compliance rate levels, 3 truck percentage levels, and 5 traffic demand volume levels resulted in 60 combinations each for early and late SDLMS, early and late SDLMS+VSL and VSL alone. For MAS, there is no compliance rate since there are no merging instructions, therefore, the MAS has a total of 15 combinations. For each run or combination, 10 iterations with different seed number were executed.

6.1 Speed Variance Analyses

As mentioned earlier, the objectives of this simulation study is to determine the safety effectiveness of SDLMS systems under VSL operation under different combinations. Crash occurrence (Taylor et al., 2000) and crash percentage (Garber and Gadiraju, 1989) increase with increase in speed variance in a particular roadway section. For that matter, speed variance has been taken as a safety surrogate measure to assess safety for all the MOT types. Tables 1 provide the detailed summary for all the MOT types for each traffic demand level, compliance rate and truck percentage. To figure out the statistical difference between speeds variances of all MOT types for each combination, overall Levene's test was performed with a null hypothesis that speed variances are not significantly different from each other. In situations where the null hypothesis was rejected, pair-wise comparison of all scenarios was made using Levene's test. Furthermore, empirical cumulative distribution function (CDF) plots were created, to visualize the effect of speed reduction for each MOT type, compliance rate, truck percentage and traffic demand volume level. In order to get the better picture of speed changes in open and closed lanes, speed variances were separately analyzed in both lanes, as explained hereunder.
6.2 Speed Variance in Open Lane

It is evident from Table 1 that for lower demand volumes (V0500) and compliance of 20%, MAS has the significantly lowest speed variance for all the truck percentages in open lane when compared to other scenarios except on one incident of C20-T10 where MAS gives significantly the highest speed variance. Speed variances under late SDLMS are significantly lower for demand volume levels of V1000 and V1500 for compliance rate of 20% and trucks percentage of 10% and 20% of the demand volume. For the same compliance rate and for 30% trucks in demand volumes of 1,000vph and 1,500vph, early SDLMS and late SDLMS produced significantly lower variances, respectively. For demand volume of 2,000vph, VSL produces significantly lowest speed variances whereas for V2500, significant lower speed variances are observed under MAS, for all truck percentages at the compliance rate of 20%.

Again from Table 1, for V0500 and compliances of 40%, MAS has significantly lowest speed variance for all truck percentages. For demand volume of 2,000vph, speed variances under early SDLMS are significantly lowest for compliance rate of 20% and trucks percentage of 10% and 20% whereas for 30% trucks, late SDLMS produced significantly lower variances. For similar compliance rate, significantly lower speed variances were recorded under late SDLMS for all truck percentages in the demand volume of 1,500vph. For demand volume of 2,000vph, VSL produces significantly lowest speed variances whereas for V2500, significantly lowest speed variances are observed under MAS, for all truck percentages at the compliance rate of 40%.

From Table 1, at 60% compliance rate and truck percentage of 10%, early SDLMS produces significantly smallest speed variance of all MOT types for low and medium volume levels (V0500, V1000 and V1500) whereas for truck percentage of 20% and 30%, MAS resulted in significantly lower speed variance for V0500 and late SDLMS presented significantly minimum variances for V1000 and V1500. At 80% compliance rate and truck percentage of 10%, early SDLMS produces significantly minimum speed variance of all MOT types for low and medium volume levels (V0500 and V1000) whereas for truck percentage of 20% and 30%, MAS resulted in significantly lower speed variance for V0500 and late SDLMS gave significantly minimum variances for V1000 and V1500. For both 60% and 80% compliance rate and demand volume levels of V2000 and V2500, it was found that the VSL and MAS produced significantly lowest speed variances, respectively.

6.3 Speed Variance in Closed Lane

It is evident from Table 1, that for lower and medium demand volumes (V0500, V1000 and V1500), late SDLMS has the significantly lowest speed variance for all compliance rates and truck percentages in the closed lane when compared to other scenarios except on two occasions; V0500-C20-T30 and V1000-C60-T10, where MAS and late SDLMS+VSL give significantly lowest speed variances, respectively.

Table 1 further reveals that for demand volume of 2,000vph, significantly lowest speed variances were observed under VSL alone operations for all compliance rates and truck percentages. Whereas, for demand volume of 2,500 vph, MAS resulted in significantly lowest speed variances for all compliance rates and truck percentages except for compliance rate of 20% and 30% trucks.
Same as in the case of open lane, Table 1 clearly depicts that addition of VSL significantly enhances the safety of the vehicles traveling in the closed lane when traffic demand volume is 2,000vph and is the second best option after MAS for demand volumes of 2,500vph.

It is also demonstrated in Table 1, that addition of VSL does not show much improvement in decreasing the speed variances for any compliance rate or truck percentage for low and medium demand volume levels i.e. V0500, V1000 and V1500. For demand volume of 2,000vph and for any compliance rate or truck percentage, early SDLMS+VSL resulted in significantly lower speed variance when compared with early SDLMS without VSL. Similarly, late SDLMS+VSL resulted in significantly lower speed variance for all compliance rates or truck percentages when compared with late SDLMS without VSL except for three occurrences i.e., C20-T10, C40-T10 and C80-T10, where late SDLMS+VSL showed significantly higher speed variances.

Table 1- Summary of Safety MOE (Speed Variance)
For demand volume of 2,500vph and for any compliance rate or truck percentage, early SDLMS+VSL resulted in significantly lower speed variance except for combinations C20-T30, C60-T10, C60-T20 and C60-T30. Late SDLMS+VSL resulted in significantly lower speed variance when compared with late SDLMS without VSL for compliance rate of 80% and all truck percentages. For 60% compliance, late SDLMS without VSL performed better in terms of generating lesser speed variances than with VSL. For combinations C20-T10, C40-T20 and C40-T30 late SDLMS resulted in significantly lower variances whereas late SDLMS+VSL showed significant lower variances for the rest of combinations.


Figure 4: Empirical CDF Plots of Speed for Demand Volume V2500

An empirical distribution function or cumulative distribution function (CDF) plots of speed for various demand volume levels, compliance rates and truck percentages are also plotted. These plots show that 40% to 90% vehicles traveling under integrated SDLMS and
VSL reduce their respective speeds from compliance rates, truck percentages and traffic demand levels. This gradual reduction in speed indicates lesser sudden braking in the work zone which can pose a safety hazard. For lower and medium volume levels (V0500, V1000 and V1500), it is clearly shown that addition of VSL shifts the distribution of speed towards left, thus, helping in lowering speed of vehicles within the system.

Cumulative distribution of speed for V2000 and V2500 in both open and closed lane is shown in figure 4. Only two combinations for each lane i.e. compliance rate 20% and 80% and 10% trucks, has been taken from for illustration. It is obvious from both graphs that speed distribution is smoother for integrated SDLMS+VSL than their individual controls. An abrupt drop in speed may lead to critical rear-end crashes in cases of early and late SDLMS. It is also revealed from these plots that with increase in compliance rate, VSL helps in decreasing the slope of the distribution curve for the integrated systems.

7 CONCLUSIONS AND RECOMMENDATIONS
Safety evaluation of all six MOT types tested through the VISSIM model is,
- Work Zone without VSL and without SDLMS
- Work Zone with VSL and without SDLMS
- Work Zone with VSL and Early SDLMS
- Work Zone with VSL and Late SDLMS
- Work Zone with early SDLMS and without VSL
- Work Zone with late SDLMS and without VSL

Table 1 summarizes the safety effectiveness of the six MOT types. In fact, each combination of compliance rate, truck percentage in the traffic composition and demand volume level has been summarized for speed variances of the vehicles traveling in the open and closed lane of the work zone. Only statistically significant results are presented. For each combination the results were numbered 1, through 6, 1 being the best and 6 being the worst. The best MOT types to use are highlighted “Black Color” in this table. Additionally, cells are highlighted with a “Grey Color” in cases where either early or late SDLMS with VSL showed lesser speed variance than their respective SDLMS type without VSL. From table 1, one can see that in terms of speed variances, generally, early and late SDLMS performed better in both open and closed lane than all other MOT types for low and medium volume levels (V0500, V1000 and V1500). For demand volumes of V2000 and V2500, VSL and MAS were significantly better than SDLMS combinations, respectively. It was a noteworthy finding that no matter early and late SDLMS performed poorly as compared to VSL and MAS when higher volumes were involved, but the addition of VSL improved their safety aspect by decreasing the speed variance of the vehicles traveling in both open and a closed lane.

The speed variance reduction may indirectly contribute to improving the overall traffic safety in work zones. The addition of VSL to the dynamic merge systems helped in improving the overall safety of the system by lowering speed variances of the vehicles traveling in the work zone. The passage of traffic through the work zone is made safer when a speed control is integrated to a dynamic merge system.

Future research may focus on analyzing the safety aspect of all six MOT types using deceleration rates, etc. As it is a known fact that higher speed variance is related to higher crash rates on freeways but still there is a need to verify speed variance and deceleration rate
as a safety surrogate measure for work zones. The future study may solely focus on the behavior of drivers in the reduced speed zones.

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