Dynamic Early Merge and Dynamic Late Merge at Work Zone Lane Closure

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Abstract. Several ITS-based countermeasures are currently being deployed in work-zones to enhance both the safety and the mobility of drivers. One of the functions of interest deals with lane management identified in previous studies as dynamic lane merging. The dynamic lane merging, can take two forms; dynamic early merge and dynamic late merge. Previously suggested dynamic lane merging techniques may be inefficient in short-term work zones since the installation of the lane merging equipment may be lengthy and difficult to move on short time basis. This research suggests two simplified lane merging schemes to be applied and tested on short term work zones.

INTRODUCTION

To improve traffic safety and efficiency in work zone areas, the Dynamic Lane Merge system (DLM), an intelligent work zone traffic control system, has been introduced in several states of the U.S. The DLM 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 caused by the congestion, and to prohibit them from using the closed lane to pass vehicles in the queue and merge into the open lane ahead of them (See Figures 1 and 2).

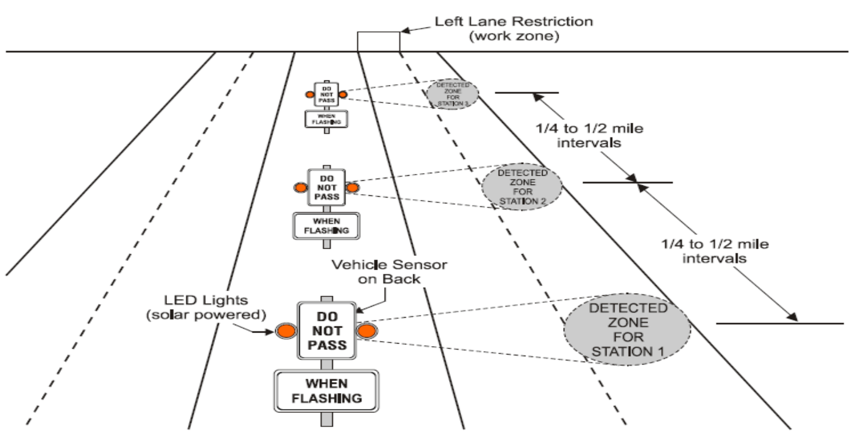


Figure 1- Indiana Lane Merge System (Source: Beacher et al., 2004)

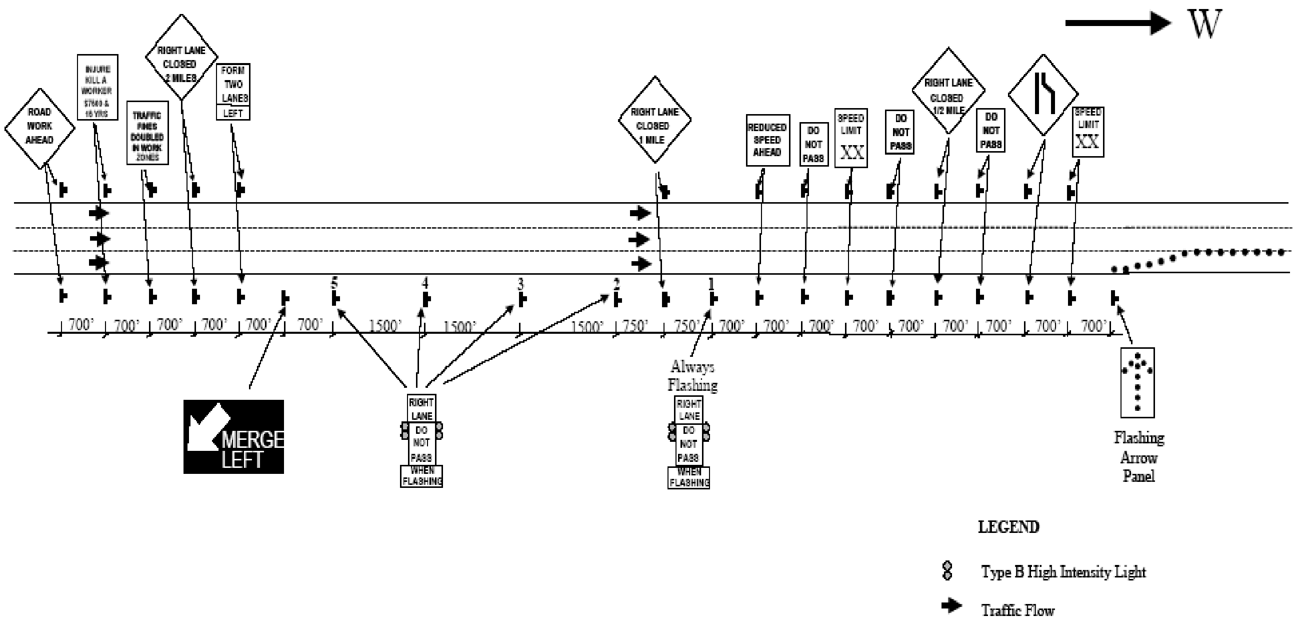


Figure 2- Dynamic Early Lane Merge Traffic Control System Used in Michigan (Source: Datta et al., 2004)

With the implementation of this dynamic system, traffic conflicts due to lane merge can be reduced and vehicles trapped in the closed lane before the work zone can be minimized. Therefore, such a system has a great potential to enhance work zone traffic safety and efficiency. 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. The combined effect of maximized storage and orderly merging operations may have the potential to increase throughput, reduce queue lengths, shorten travel times, and discourage aggressive driving (See Figures 3 and 4).

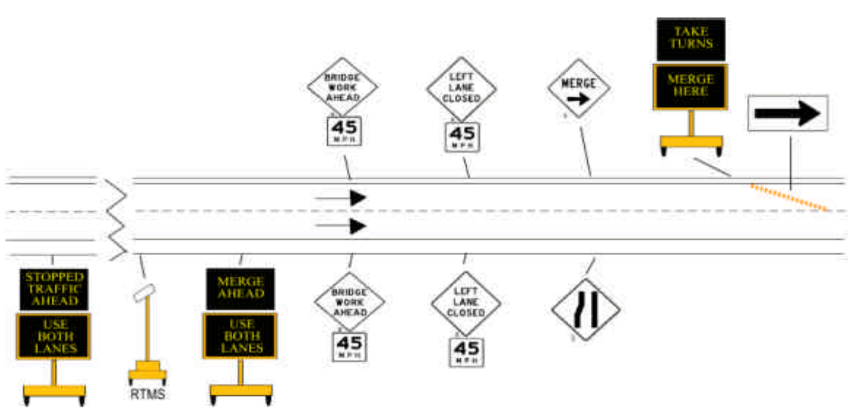


Figure 3- Minnesota's DLM

The Florida Department of Transportation addressed their interest in incorporating and testing ITS-based lane management systems into short term wok zones (e.g. milling and resurfacing jobs). Since previous DLM applications, as elaborated on in the following sections, entail extensive equipment which requires lengthy installation and calibration, the authors in accordance with FDOT believe that these systems may be inefficient in short term work zones where the work zone moves on average every 4 to 8 hours. Therefore, two simplified lane merging schemes (early merge and late merge) are designed and suggested for deployment and testing on short term work zones. The following sections elaborate on the proposed real-time lane management strategies.

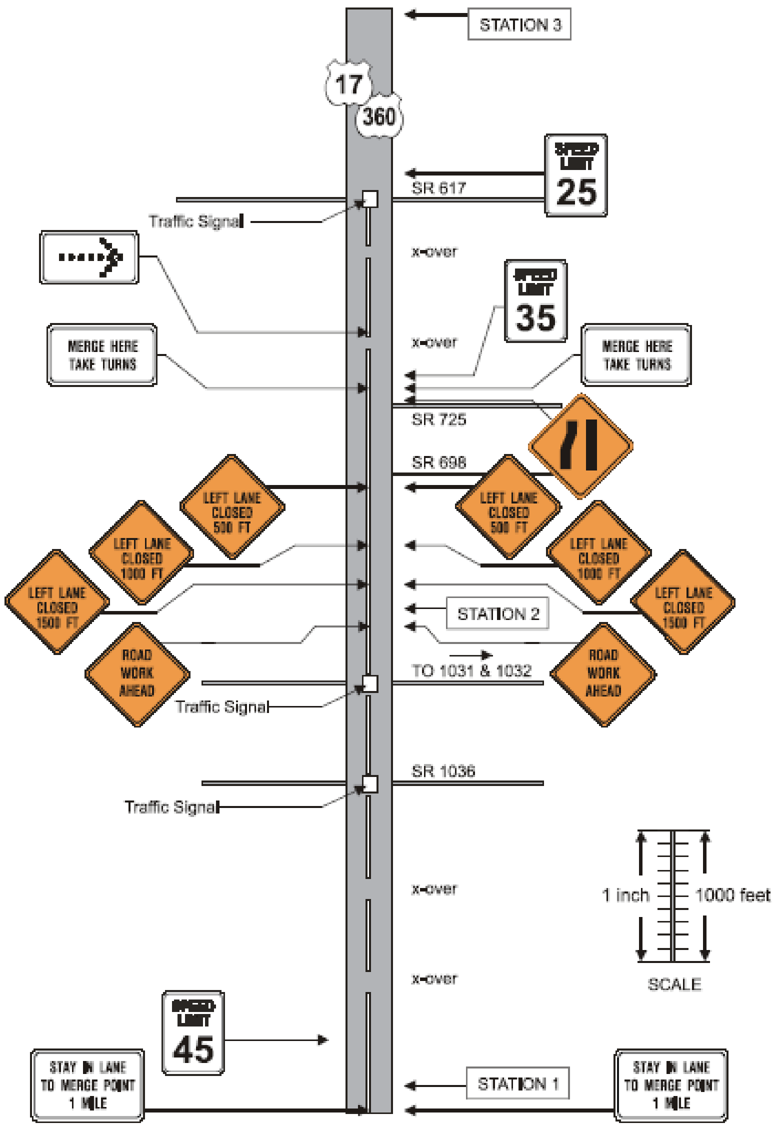


Figure 4- Tappahannock, Virginia site diagram (Beacher et al., 2004)

PREVIOUS DYNAMIC LATE MERGE APPLICATIONS

McCoy and Pesti (2001) proposed a dynamic late merge in which the late merge would be employed only at times of high congestion. McCoy and Pesti (2001) stated that the late merge can reduce congestions and delays, whereas the early merge increased congestions and delays. Beacher et al. (2004) applied the dynamic late merge system in Tappahannock, Virginia and conducted a before and after study to explore the benefits of the system. Figure 3 shows the site diagram with the dynamic late merge system. According to their results, the percentage of vehicles in the closed lane increased significantly from 33.7 to 38.8 percent when comparing the late merge to the MUTCD treatment. The throughput volumes showed no statistical difference between the MUTCD treatment and the late merge. Time in queue was not significantly different between the two types of traffic control. According to Beacher et al. (2004) the lack of improvement in throughput and time in queue may be attributable to the relatively low percentage of heavy vehicles.

In June 2003, the University of Kansas, in cooperation with the Kansas Department of Transportation and the Scientex Corporation deployed the Construction Area Late Merge (CALM) system in Kansas (Scientex; Meyer. 2002). This system is the dynamic version of the Late Merge Concept introduced by Penn DOT. This system employs traffic detectors to sense congestion upstream of a construction lane closure. The traffic data is communicated in real-time to a central controller where proprietary software algorithms determine the critical thresholds of traffic density and speed to activate real-time messages directing motorists to remain in their lanes until they approach the lane closure, where they merge alternately by taking turns. The results showed that the average volume through the work zone was enhanced after the drivers were accustomed with the system. However, the net change in volume did not show a significant improvement over baseline values.

Maryland's Dynamic Late Merge (DLM) System comprises a set of 4 portable CMS and 3 RTMS detectors that are added to the standard static traffic control devices utilized at construction lane closures. The CMS furthest upstream (~1.5 miles) from the taper alternated between the messages "USE BOTH LANES" and "TRAFFIC BACKUP". The next two CMS located at approximately ½ mile and ¼ mile from the taper itself, the final CMS alternated between messages "TAKE YOUR TURN" and "MERGE HERE". The University of Maryland, College Park conducted the evaluation of the system by utilizing one day of baseline (or control) data where the road closure utilized only the standard static traffic control signs. This was followed by 4 days with the DLM system activated. The results showed that more vehicles were in the discontinuous lane. Many drivers were observed merging before the designated merge location during the evaluation period. These early merges resulted in multiple merging points and appeared to result in some confusion on the proper place to merge. The queue lengths were observed to be reduced between 8% and 33% during the 4 days evaluation with the activation of the DLM System. Unfortunately, numerous traffic conflicts were observed between the two-lane traffic. These conflicts resulted in conditions of stop and go traffic. The authors finally stated that the advantages of the DLM system are increased throughput, shorter queue lengths, and more uniform distribution of lane use before the taper.

The Minnesota Department of Transportation (MnDOT) evaluated the Dynamic Late Merge System (DLMS) which consists, in addition to the standard orange and black warning signs placed in advance of the lane closure, of three Changeable Message Signs (CMS) and a Remote Traffic Microwave Sensor (RTMS) detector (See Figure 4). When congestion begins to form, the signs are activated to provide lane use instructions to drivers. The CMS farthest from the work zone displays the message “STOPPED TRAFFIC AHEAD-USE BOTH LANES”. The next CMS sign reads “USE BOTH LANES-MERGES AHEAD”. The sign closest to the work zone will show alternating messages of “TAKE TURNS-MERGE HERE”. When traffic speeds increase as congestion dissipates, the signs will turn off and the system will return to the typical static work zone traffic control that encourages early merging (Dynamic Late Merge System Evaluation)

PREVIOUS DYNAMIC EARLY MERGE APPLICATIONS

The dynamic early merge system creates a NO-PASSING zone upstream of a work zone taper based on real-time measurements of traffic conditions (Tarko and Venugopal, 2001). The system consists of queue detectors and “DO NOT PASS WHEN FLASHING” signs that would be triggered by the queue detectors. When a queue is detected next to a sign, the next closest sign’s flashing strobes, upstream, are activated creating the NO-PASSING zone. This system makes queues jumping an illegal task. Figures 1 and 2 illustrate this system**.**

The ILMS was tested in the field in the 1997 construction season by the Indiana Department of Transportation. It was found that the system smoothes the merging operations in advance of the lane closures. Drivers merged when they were supposed to merge, the flow in the open lane was uniform, and rear-end accident rates decreased. However, this system did not increase the throughput and the results of a simulation study conducted by Purdue University indicated that travel times through work zones with ILMS are larger (Tarko, 1998).

In 1999, the University of Nebraska conducted a study of the Indiana Lane Merge System (ILMS) on I-65 in the vicinity of Remington, Indiana. This study was limited to a four day data collection exclusively under uncongested conditions. In this project, the right lane was closed and the data collected (by video cameras and laser speed gun) and extracted included traffic volumes, speeds, conflicts, lane distributions, flows, and time headways. Comparing the ILMS with the standard MUTCD merge control, the results showed that the ILMS increased the capacity to some extent (from 1,460 to 1,540 vphpl). As for the safety aspect of the ILMS, since the data collected was limited to uncongested conditions and to 16 hours of video data, it was not clear whether the ILMS improve safety in terms of number of forced merges (McCoy et al., 1999).

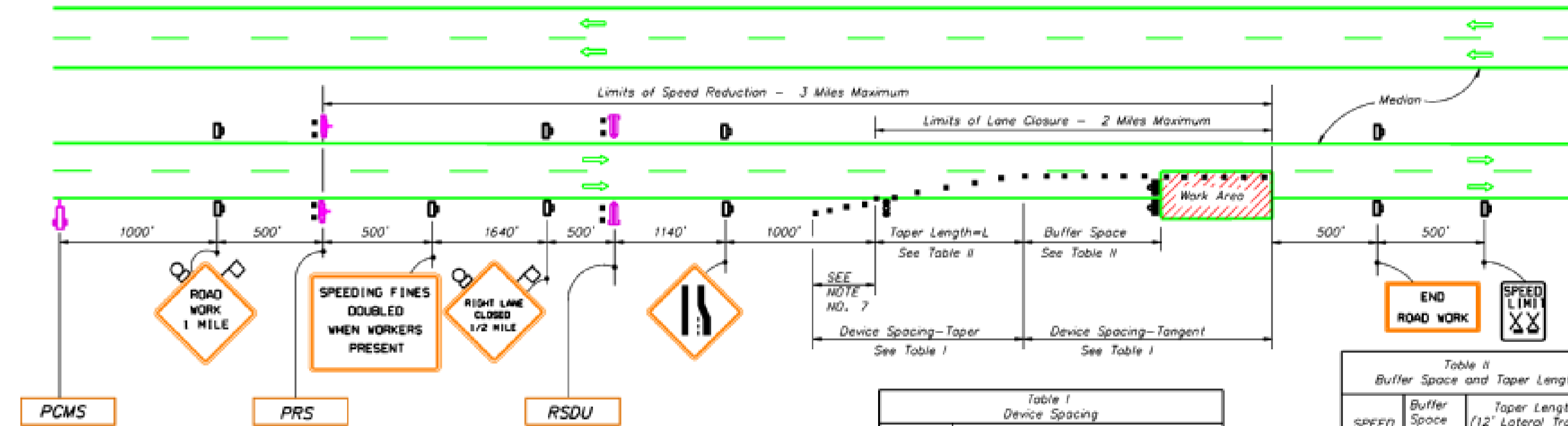
The ILMS was also studied by Purdue University and the results were detailed in a report published in 2001. This system was studied on I-65 near West Lafayette, Indiana. This project entailed extensive data collection under both congestion and uncongested conditions for a duration of four months in 1999. Multiple loop detectors and two cameras were used for data collection. Purdue University studied both the safety effects of the ILMS by developing conflict frequency models as well as capacity effects of the ILMS. The results of the analyses showed that the ILMS decreases the capacity by 5%. The Authors mentioned that the decline in the capacity may be due to the unfamiliarity of the drivers with the system (Tarko and Venugopal, 2001).

The Wayne State University conducted a study to assess the ILMS commonly referred to as Michigan Lane Merge Traffic Control System (LMTCS). This study compared four sites where the system was installed to four control sites where traditional MUTCD merge was implemented. The “DO NOT PASS WHEN FLASHING” signs were activated manually by personnel on the four sites. The lane closure configuration and geometry of freeway sections were homogeneous in the test and control sites for consistency. The data collected included aggressive driver behavior, location of merging, presence of law enforcement. In addition to that, the floating car method was utilized to record travel times and delays. According to their results the ILMS (or LMTCS) increased the average operating speed, decreased the delays (49 vehicle hours of delay per hour), decreased the number of aggressive driving maneuvers during peak hours (from 73 to 33) (Wayne State University, 2001).

SUGGESTED LANE MERGING SCHEME FOR SHORT-TERM WORK ZONES

Currently the Motorist Awareness System (MAS) is employed by FDOT on short term work zones. Figure 5 shows the MAS system in use according to Index- 670 from the FDOT standards. As shown by the Figure 5, the MAS consists of an advanced warning arrow panel at the lane taper, one portable changeable message sign (PCMS), two portable regulatory signs (PRS) with flashing beacons, two radar speed display units (RSDU), and other regulatory signs.

In order to simplify the dynamic lane merging equipment relocation, installation and calibration, this research proposes the addition of only one portable changeable message sign and one sensor trailer to the current MAS system. Therefore, instead of moving, installing and calibrating multiple traffic sensors and PCMS, which may be a lengthy process for a short term work zone, one shall relocate one PCMS and one sensor trailer every time the work zone moves. As shown by Figure 6, this research proposes the addition of one Portable Changeable Message Sign (PCMS) and one traffic sensor trailer. It should also be noted that the first site is selected by UCF and FDOT and Figure 6 shows the site-specific modified MOT plan that is signed and sealed and ready for implementation.



See General Note No. 1

Typical PCMS Display

With speed reduction:
Message 1: WORKERS PRESENT AHEAD
Message 2: SPEED REDUCED NEXT 3MI

Without speed reduction:
Message 1: WORKERS PRESENT AHEAD
Message 2: NEXT 3 MILES

Table I
Device Spacing

Speed (mph)	Max. Distance Between Devices (ft.)			
	Cones or Tubular Markers		Type I or Type II Barricades or Vertical Panels or Drums	
	Taper	Tangent	Taper	Tangent
25	25	50	25	50
30 to 45	25	50	30	50
50 to 70	25	50	50	100

Table II
Buffer Space and Taper Length

SPEED (MPH)	Buffer Space	Taper Length (12' Lateral Transition)	
	DIST. (FT.)	L (ft.)	Notes (Merge)
25	155	125	$L=\frac{WSd}{60}$
30	200	180	
35	250	245	
40	305	320	
45	360	540	$L=WS$
50	425	600	
55	495	660	
60	570	720	
65	645	780	
70	730	840	

Figure 5- Motorist Awareness System (MAS) in Florida (Index 670 FDOT-standards)

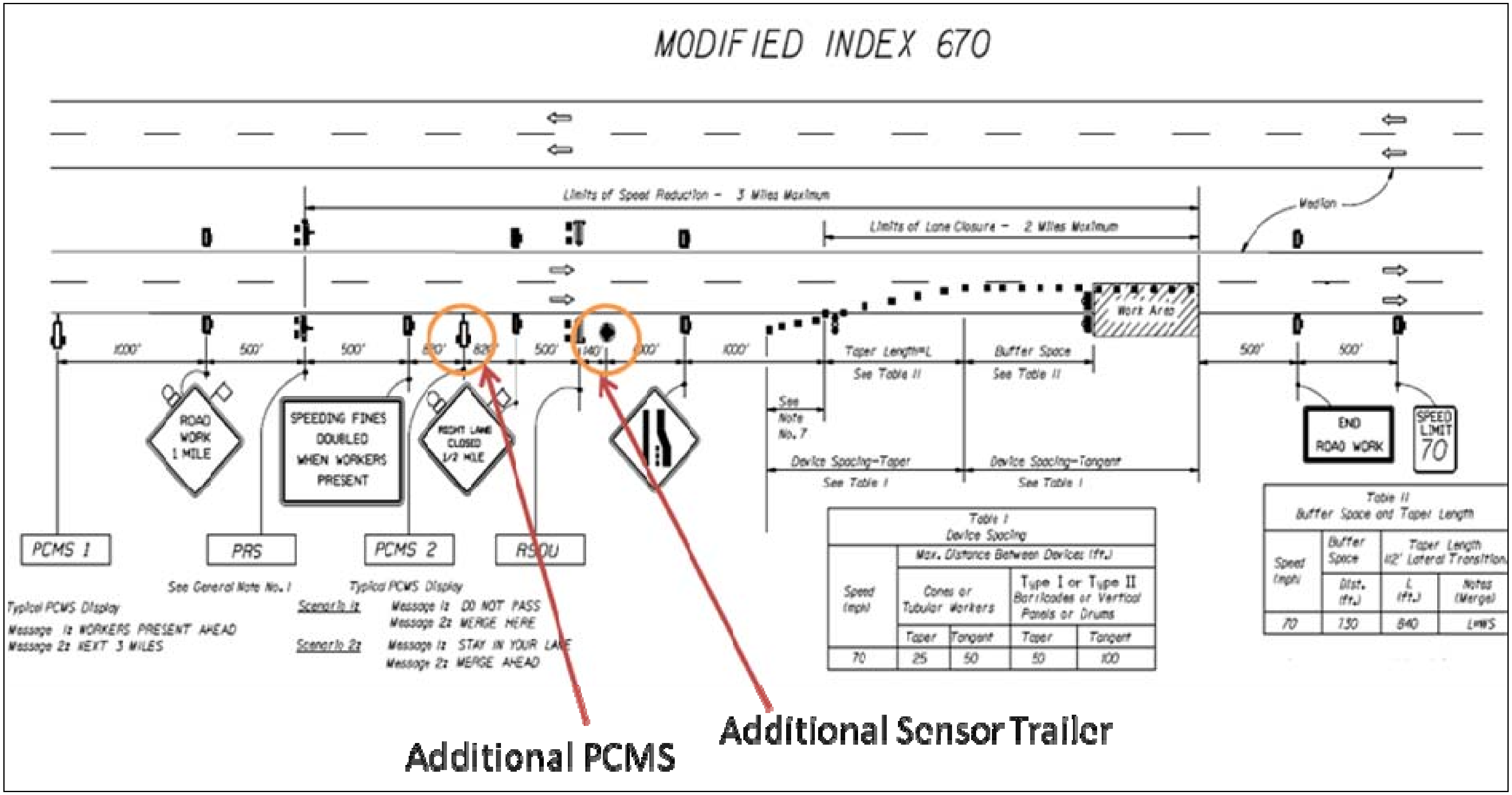


Figure 6- Suggested DLM (index 670 modified)

SUGGESTED DYNAMIC LANE MERGING SYSTEM COMPONENTS AND COMMUNICATION

The Dynamic Lane Merge System (DLMS) shall consist of one set of the following equipment.

- ***Traffic detection stations*** wirelessly linked to central computer base station. The traffic sensor will be an RTMS (Remote Traffic Microwave Sensor) sensor.

- ***1 central computer base station*** environmentally hardened and equipped with appropriate software and dedicated wireless communications to "link" with the traffic sensor station and the PCMS.

- ***Wireless communication links*** consisting of Road-side Remote Stations (RRS), duly equipped with radio modems (for transmitting and receiving licensed UHF radio frequencies), micro- processors and antennae.

- ***Portable Changeable Message Signs (PCMS)*** remotely controlled via a central computer base station or central system controller (CSC).

Figure7- Additional Sensor Trailer and Additional PCMS

FUTURE RESEARCH

Up to date there are no studies that compare the dynamic late merge to the dynamic early merge in the field. Therefore, three scenarios will be tested in the field. The first scenario will be the application of the MAS system solely which will be the base case. The second scenario will consist of implementing the dynamic early merging scheme which will be test1 case. The third scenario will consist of implementing the dynamic lane merging which will be the test2 scenario. MOEs including travel times, delays, speed variances, demand volumes, throughput volumes, and vehicle classification will be compared. Accordingly, the results will be analyzed and recommendations on the implementation of each merging scheme will be provided.

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