DYNAMIC WORK ZONE SAFETY SYSTEM

Author (Presenter):

Rod Klashinsky
Senior Manager, International Road Dynamics Inc.
702 43rd Street East
Saskatoon, Saskatchewan S7K 3T9
Phone: (306) 653-6600 Fax: (306) 242-5599
e-mail: rod.klashinsky@ird.ca

Co-Author:

Rob Bushman, P.Eng.
Advanced Applications Specialist, ITS Solutions Group
International Road Dynamics, Inc.
702 43rd Street East
Saskatoon, Saskatchewan S7K 3T9
Phone: (306) 653-6600 Fax: (306) 242-5599
e-mail: rob.bushman@ird.ca

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ABSTRACT

Frequently, aggressive motorists pass other vehicles, invading the traffic stream near the taper to a work zone area in order to gain a slight time advantage. This dangerous practice has become quite common and is considered to be a significant cause of work zone accidents, even deaths.

A Dynamic Work Zone Safety System has been developed which controls this problem. Utilizing a series of flashing traffic signs which are activated by traffic sensors when traffic queues are formed, the system assists in the prevention of dangerous merging prior to the taper of a work zone. The objective is to get motorists to merge as soon as possible so traffic flows more smoothly.

The system creates a dynamic "no passing" zone. There are a series of enforceable "Do Not Pass When Flashing" signs. The lights on the sign closest to the work zone are always flashing. A sensor on that sign detects when traffic starts to back up in the area. It then transmits a signal to the next sign farther ahead of the work zone and its lights begin flashing. This action is repeated along the length of the control zone where signs are located, as traffic continues to back up.

This paper discusses the results of the Dynamic Work Zone Safety System as used in the State of Indiana. The conclusion is that the system reduces dangerous merging practices prior to work zones and even leads to a reduction in road rage.

INTRODUCTION

During the last five years, an average of 760 fatalities per year resulted from motor vehicle crashes in work zones in the United States. Approximately 39,000 people were injured as a result of motor vehicle accidents in work zones. (1)

The safety of highway construction workers and motorists in work zone areas continues to be a concern for many people and organizations. A recent study indicated that two to three percent of the total police reported accidents for several States were work zone accidents. There are many aspects to improving the safety of these areas including reducing speeds, improving visibility, providing worker protection, and improving traffic flow. The same study on work zones also indicated that the distribution of rear end and side-swipe accidents was higher for work zone accidents than non work zone accidents. (2)

A unique system has been developed to address the traffic flow problems that can occur at a construction site, including the rear end and side-swipe incidents that occur more frequently under these circumstances. The Dynamic Work Zone Safety System, developed by International Road Dynamics Inc. (IRD) in partnership with Indiana DOT addresses the specific problem of merging traffic from two lanes into a single lane.

As traffic approaches an area with a lane restriction, most vehicles will merge into the single continuous lane and proceed in an orderly fashion through the work zone. However, frequently aggressive drivers will stay in the dropped lane until the last moment in an attempt to get further ahead in the queue. They must then perform a dangerous merge maneuver in congested traffic with limited time and space available.

There are at least three problems that arise from this kind of action. First, there is the risk of an accident during the actual lane merge itself, since there are few openings in the continuous lane for a vehicle to merge and aggressive driving is often involved. Secondly, if the lane merge is successfully completed, it has likely disrupted the flow of traffic. Someone has had to slow down or stop in order to create an opening for the incoming vehicle, forcing all vehicles behind to adjust speed as well. As the number of traffic disruptions increases, so does the potential for rear-end accidents and other incidents. Although incidents may not occur at the merge point, the impact may be felt further upstream. The third aspect is the perception and attitudes of drivers. Drivers who pass a waiting line of traffic in the continuous lane and then make a merge into the front of the line obtain an unfair time saving over those who stay in the continuous lane. This increases the impatience, anxiety, and anger level of many who must now wait longer. These feelings will linger and may affect the driving habits and aggressiveness of drivers further down the road.

The Dynamic Work Zone Safety System addresses this type of behaviour. The system creates a no passing zone of adjustable length based on the current traffic flow characteristics. A working, automated version of the system was developed by IRD and Indiana DOT and implemented at selected construction sites with favorable results. The operation of the system and the results are explained in greater detail in the following sections.

OPERATION OF A DYNAMIC NO PASSING ZONE

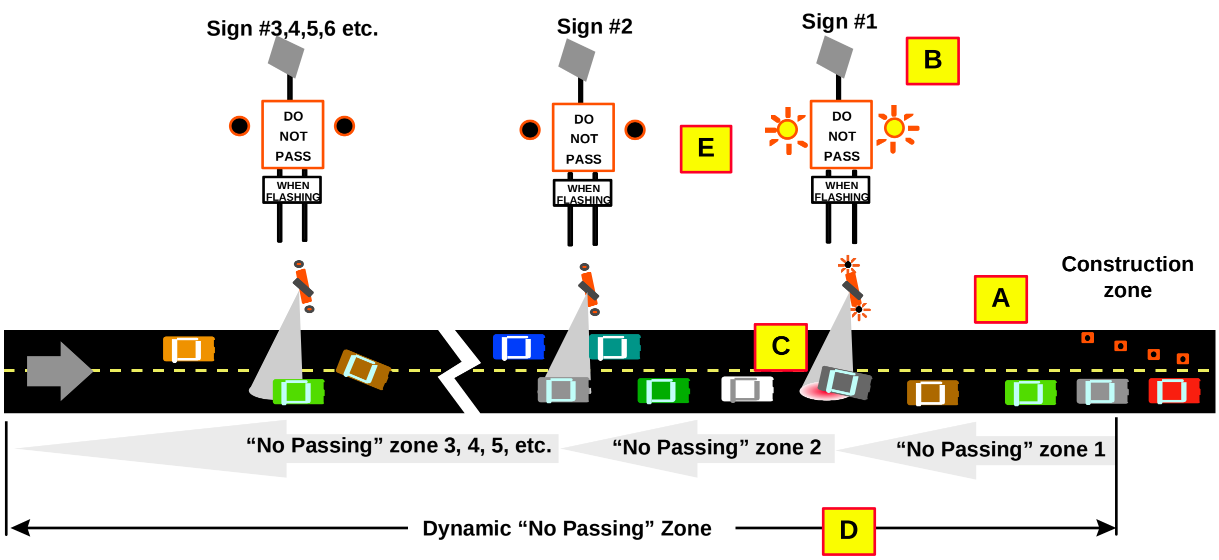
Vehicles can be prevented from attempting to enter the continuous lane at the lane drop point by creating a no-passing zone in advance of the construction zone. This will force all vehicles into the continuous lane before the final merge point, avoiding many of the problems discussed in the introduction. However, the traffic volumes and congestion will vary greatly throughout the day at the construction zone. As a result, the point at which vehicles can be moved smoothly into a single lane will also vary greatly during the day. As congestion increases and the queue in the continuous lane lengthens, the opportunity for smooth lane changes moves further back from the last possible merge point.

The Dynamic Work Zone Safety System is designed to automatically react to the changing queue length and flow conditions and adjust the length of the no passing zone. As congestion occurs at a certain point, the no passing zone must be moved upstream of this point to provide vehicles with time and space to merge while traffic is still moving and there are sufficient openings.

The dynamic no passing zone is created by using a series of static traffic signs and traffic signs with flashing beacons. Refer to Figure 1 for an illustration of the system layout. Several static signs are located nearest to the lane drop point to create a permanent no passing zone in this area. In addition, a series of 3 to 6 control stations with static signs and flashing beacons are installed further upstream from the lane drop. These signs contain the message “DO NOT PASS WHEN FLASHING”. The entire sign and message is in conformance with the MUTCD standards. By turning the beacons on or off, the length of the no passing zone can be adjusted to match the traffic flow characteristics.

The equipment for each control station is mounted on a small trailer so that it is portable. This allows the system to be moved at a site as construction progresses or moved to another site with relative ease. Each control station is equipped with a static sign and flashing beacons. Each station, except the one furthest upstream, is also equipped with a traffic monitoring device. The traffic monitoring device is a non-intrusive sensor provided by IRD. The sensor monitors passing traffic to determine vehicle presence and lane occupancy.

The information from the sensor is processed to determine vehicle flow at that particular point. If congestion is detected a signal will be relayed by radio frequency (RF) communication to the next upstream station. The sign at the upstream station will be activated to extend the no passing zone. In this way, vehicles will have been directed into the continuous lane prior to reaching the congested area.



A. Construction creates a lane restriction on a two lane, one direction roadway.

B. The Dynamic Work Zone Safety System creates a dynamic "No Passing Zone" just in advance of the lane restriction. The traffic sensors, which are entirely non-intrusive, are mounted on the sign structure and used to detect traffic queue lengths. Sign #1 is always activated to warn of the lane restriction.

C. When vehicle congestion is detected at Sign #1, the second warning sign is automatically activated. When vehicle congestion is detected at Sign #2, the third warning sign will be activated, and so on.

D. The "No Passing Zone" is dynamic. Each "No Passing" sign is automatically activated/deactivated in sequence as changing conditions in vehicle congestion are detected by the traffic sensors.

E. Activated signs have flashing lights, non-activated signs have lights turned off.

F. Anyone attempting to pass the waiting traffic queue and then invading the traffic stream near the taper would be subject to traffic citation, since the "No Passing Zone" sign is an enforceable regulatory sign.

Figure 1 - Dynamic Work Zone Safety System Layout and Operation

Power for the sensor, controller, RF communication, and beacons is provided by solar panels mounted at the top of the sign pole. A battery back up is included to provide continuous service during adverse weather conditions.

A configurable setting is included in the system to control how long the beacons will continue to flash once activated. When the congestion point is near to one of the stations, the congestion level may vary around the threshold value for activating the upstream sign. Under these conditions it would be undesirable to have the status of the upstream sign change many times in a short period of time. For this reason, once activated a station will stay active for a minimum period of time, creating stability in the system. The activation time should be of sufficient length for stable operation of the system. If the activation time is too long, the system will be slow to respond to a decrease in congestion and will remain in place long after the congestion has been relieved. A setting of five minutes for this value is recommended to provide good operation under normal conditions. (3)

The station closest to the construction zone will always be activated, since there is no downstream information available. This station creates the beginning of the permanent no passing zone. The permanent no passing zone is further identified by several static signs with no flashing beacons or automation.

The station farthest from the construction zone is not equipped with traffic monitoring equipment. This station will receive information from the downstream station and be activated in the same manner as the other stations. However, since there are no stations farther upstream to be activated, there is no need for traffic monitoring at this location.

OPERATIONAL RESULTS

The system which has been described in the previous section has been used at several road construction sites. During the time the system was in operation, data was collected on the effects of the system operation at freeway construction zone locations. In addition, many observations were made on the system effectiveness.

The work zone system is feasible if the following conditions are met (4):

- The work zone has to be a reasonably long (at least about 0.8 km) for drivers to adjust to a desirable speed in the work zone.
- The freeway should have heavy traffic so that the flow reaches the capacity of the work zone and queues are formed. This is important because the driver's compliance to control becomes more critical when the flow in the work zone is at its capacity.
- There should not be any on/off ramps for about 3 to 5 km in the approach zone and also no on/off ramps within the work zone.

The data collected included inflow, density, speed, and volume at several key points. The data was collected in both the continuous and the drop lane prior to the no passing area, in the no passing area, and in the continuous lane after the other lane had been dropped. Test periods were then run with the system operating and not operating. In-flow during both test periods were consistent, providing a valid basis for comparison of the results.

The density and volume measurements indicate the pattern of traffic flow through the area (see figures 2a, 2b, 3a, 3b as attached). When the control system was put in place a drop in the density and volume was observed in the dropped lane. A corresponding increase in volume and density was observed in the continuous lane. This is an indication that the system is having the desired result. More vehicles are moving from the dropped lane to the continuous lane earlier with the system in place than without the system. This will result in a decrease in the number of merges that must take place near to the lane drop point.

It was also found that the travel time for a vehicle that is in the continuous lane decreases with the system in place. This is a result of reducing the number of vehicles that are cutting into the queue and forcing those behind to wait longer.

The actual speed and volume of traffic through the construction zone itself did not increase. This is not surprising since after all of the vehicles are in the continuous lane, the speed and volume will be determined by factors in the work zone itself. These factors will limit the speed and volume, and are the same regardless of whether the system is in place. The purpose of the Dynamic Work Zone Safety System is to get vehicles into the continuous lane at the start of the construction zone in a safe, orderly and efficient manner. Once the vehicles reach this point, the system has achieved its purpose. Since high speed is often a contributing factor to work zone accidents, an increase in speed and volume may not actually be a desirable outcome.

It was also observed that the speed of vehicles in the continuous lane was more uniform with the system in place. This is a result of reducing the aggressive and abrupt lane changes which disrupt the flow of traffic. (5)

Having the system in place also improves the ability of the highway patrol to monitor and enforce proper driving in the construction zone. When a “MERGE” sign is used to direct vehicles into a single lane, non-compliance is not enforceable by the State Patrol. However, no passing zones are fully enforceable by the State Patrol and established in law in Indiana. The signs are MUTCD and supported by law. Enforcement on a periodic basis is critical and has proven successful and there have been no court challenges to date. With periodic enforcement, the behaviors of many drivers can be altered.

Since the development of the Work Zone Safety System, additional systems have been deployed in Indiana, Kentucky, and Michigan. The system has been included as a mandatory requirement at certain locations as part of construction tenders.

CONCLUSION

Indiana Department of Transportation and International Road Dynamics developed a system to address a specific problem behavior at construction zone sites. Vehicles traveling in the dropped lane were causing difficulties when they tried to merge at the drop point under congested traffic conditions. This action results in high accident potential at the merge point, higher accident potential upstream of the merge point, and aggravated drivers throughout the work zone.

The Dynamic Work Zone Safety System is simple and portable and can be easily implemented at a construction zone with a standard layout. Since the system is portable it can be advanced as construction work advances or moved to another site.

Results indicate that the system has the desired effect on traffic flow. When the system is in operation it improves the early merging of traffic into the continuous lane, reducing the late lane changes which are the cause for safety concerns. It is also an effective aid in assisting enforcement of proper driving behaviour by highway patrols. The Dynamic Work Zone Safety System continues to be deployed at various sites to provide safer and smoother flow of traffic through construction zones.

REFERENCES

1. U.S. National Work Zone Safety Web Site
2. Highway Safety Information System
3. A. Tarko, S. Kanipakapatnam, J. Wasson, Manual of the Indiana Lane Merge Control System, FHWA/IN/JTRP-97/12 Part 2, (West Lafayette, IN: Purdue University, 1998), p. 16.

4, 5. A. Tarko, S. Kanipakapatnam, J. Wasson, Modeling and Optimization of the Indiana Lane Merge Control System on Approaches to Freeway Work Zones, FHWA/IN/JTRP-97/12 Part 1, (West Lafayette, IN: Purdue University, 1998), pp. 35-39.

FIGURES

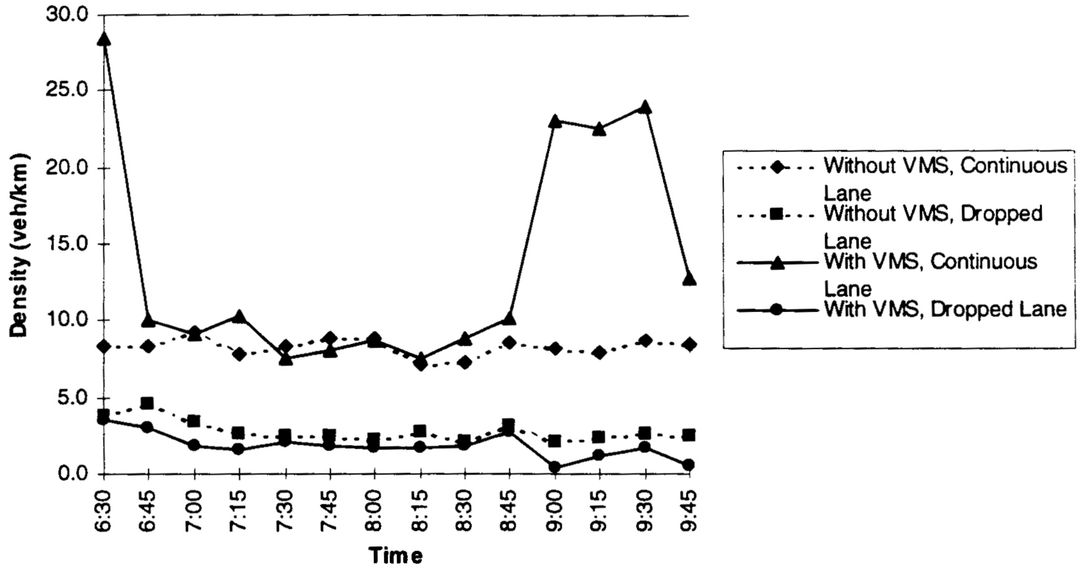


Figure 2a - Density Variation 1.25 km to Lane Drop (Detector Location 2)

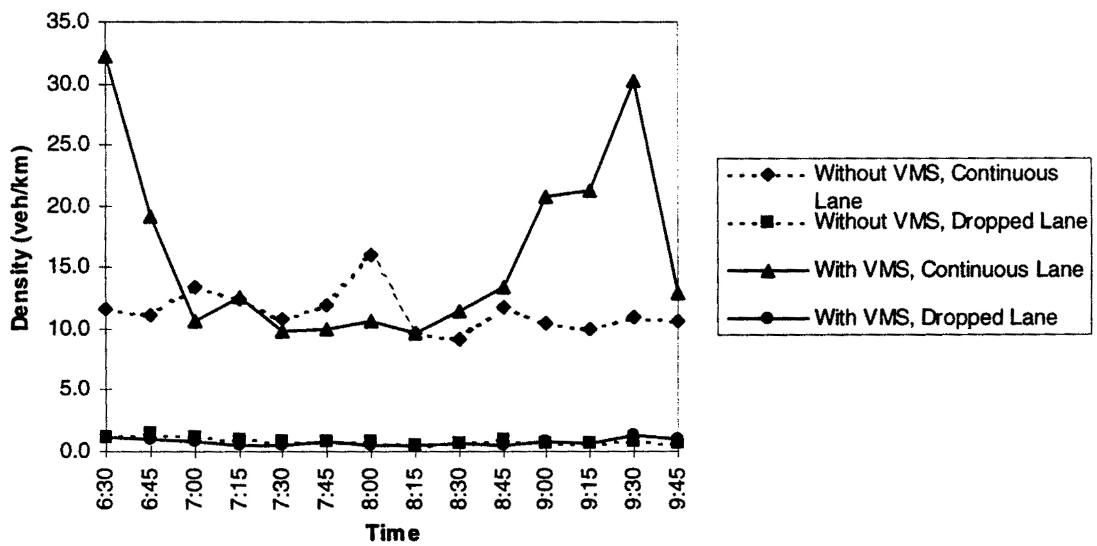


Figure 2b - Density Variation with Time at 0.05 km to Lane Drop (Detector Location 3)

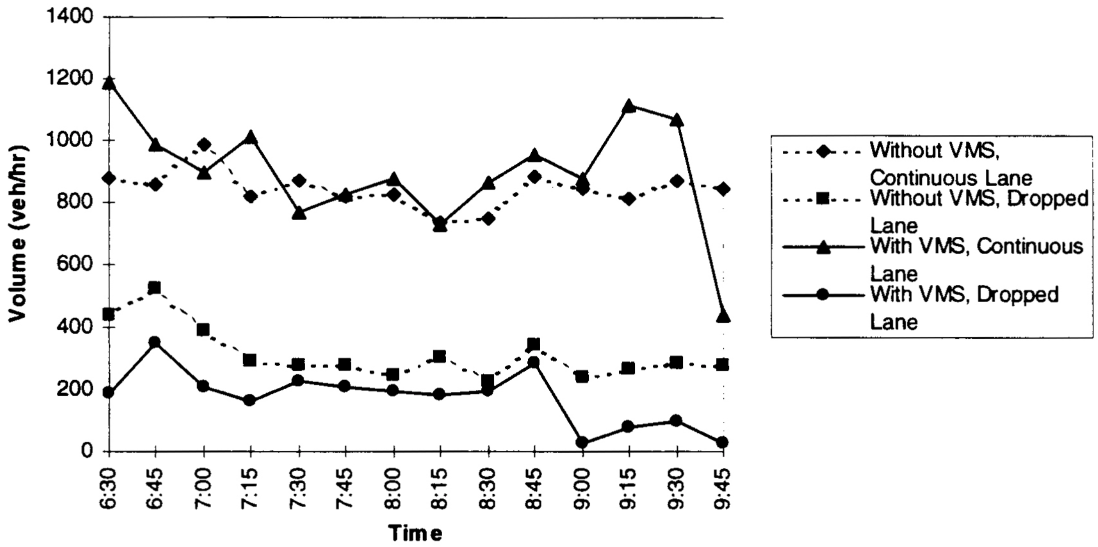


Figure 3a - Flow Variation with Time at 1.25 km to Lane Drop (Detector Location 2)

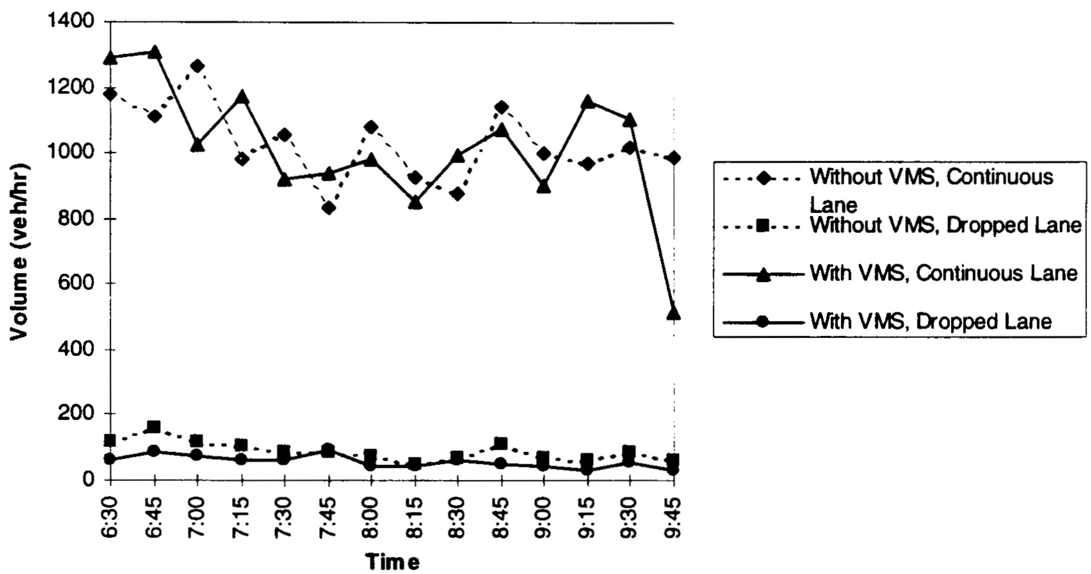


Figure 3b – Flow Variation with Time at 0.05 km to Lane Drop (Detector Location 3)