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Changing Lane Assignment Dynamically Using Variable Message Signs Technique

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Abstract— **The goal of dynamic lane changing strategy is to reduce the conflict of lane-changing maneuvers by clearly defining turning lanes. This paper examined and modeled the new possible application of variable message signs (VMS) on dynamic lane usage concept using ARENA simulation software. The data was collected on a signalized intersection in Al-Khobar City in Suadi Arabia. VMS's should be used to display the current assignment and lane-changing restrictions. Results indicate that the queue time were reduced in both peak periods due to VMS usage, and it could be further enhanced if this usage is covered with some kind of enforcement. It was clear that the possibility of using VMS as a tool for dynamically lane assignment at signalized intersection 'which was indicated through ARENA simulation' proved to be quite promising.**

Keywords— **Conflict, Queues, Traffic Safety, Turning Lanes, Variable Message Sign.**

I. Introduction

Currently, turning lanes locations at intersections are defined by drivers' lane-positioning decisions, and this often causes undesirable conflict. One of the most fundamental technologies available for displaying traffic-related information from the roadside is the Variable Message Signs (VMS). The reasonably good expected effect of VMS in the study area excited the researcher to use VMS technology in solving one of the bad practices in the area. VMS can be used to segregate drivers by destination and encourage them to change lanes in line with their direction. VMS upstream the intersection would be similar to pavement markings but programmed for a variable time periods (based on morning or evening peak periods). This lane-assignment strategy should be strengthened by signs and regulations. VMS technique is being introduced in certain locations in Saudi Arabia highways. Currently these VMS display general information messages not directly related to traffic situation. The aim of such effort is just to get drivers acquainted with the VMS technology. The response of drivers to VMS related to current traffic condition is not known yet.

II. Literature Review

VMS is also known as Changeable Message Signs (CMS) or Dynamic Message Signs (DMS). VMS is defined as a sign for the purpose of displaying one of a number of messages that may be changed or switched on or off as required (CEN, 2005). VMS messages are classified into two main categories from the perspective of their usage to the drivers: passive and active (Lim, 2005). A survey aimed to explore the drivers' response to different VMS messages in London through two approaches. In the first approach, the effect of different VMS messages on drivers' diversion rate was evaluated using questionnaire survey. The respondents indicated that VMS is a useful control tool, and they support the use of VMS in the future. In the other approach, a survey of drivers' actual responses to a message activation showed that only one-third of the drivers saw the information presented to them and few of these drivers diverted, although many found the information useful. This number represents only one-fifth of the number of drivers expected to divert from the results of the questionnaire (Chatterjee et al. 2002).

In another survey in Wisconsin, the road users' opinion on travel conditions and their knowledge about VMS were evaluated. The main findings of this survey showed that about 40% of the drivers indicated that they are familiar with VMS technology. They indicated that VMS enhances safety, improve travel efficiency, and reduce driving time (Ran et al. 2004). The project of Wang et al. (2006) listed several VMS survey studies. In the Washington, D.C. area, a drivers survey was conducted to assess their previous response to VMS. The results indicated that about half of the participants usually responded to VMS while 38% occasionally responded to VMS. In Amsterdam, based on survey study, more than 70% of the drivers indicated that they were sometimes influenced by VMS information. In Paris, a survey conducted found that 70% of the drivers believed that VMS are useful. The study indicated that young drivers are less prone to comply with VMS advice.

A study by Richards and McDonald (2007) listed several VMS survey studies. In Toulouse, 7% said they always followed the recommended directions, 30% said sometimes and 63% said never. In Turin, about 20% of all the drivers or nearly 90% of those drivers who had seen the VMS followed the directional advice. User acceptance of VMS was studied in an urban road network in Southampton, UK. The public perceived effectiveness and usefulness of these signs through the use of questionnaire surveys and travel diaries was investigated. The results showed that the VMS messages were well understood and legible.

A study on comprehension of VMS was carried out in Finland, England and Italy. The study investigated the drivers understanding of the factors that control the VMS display. It was concluded that gender and driving experience did not influence the results, but country did (Nygardhs and Helmers, 2007). A study in Trondheim investigated the impact of six VMS using simulations and user surveys. This study indicated that most drivers in the city consider VMS as useful, while a few altered their route as a result of the information displayed on VMS (Hoye et al. 2011). To assess the drivers' response to VMS, trials in several locations between two cities in Sweden were conducted. A minimum of 6% of the drivers responded to VMS suggesting alternative routes to avoid congestion in one location, while the maximum response reached 40% in other locations. It was found that when 30% of the drivers responded to the VMS signs, a maximum delay was controlled. At peak times, a diversion of 10% may be adequate for traffic relief (Davidsson and Taylor, 2003).

The study of (Daganzo 2002), presents the strategy of dynamic lane assignment for improving freeway performance and congestion mitigation to define weaving sections. VMS would be used to tell drivers in what lane to be according to their destination. Messages would be similar in spirit to pavement markings but programmed for fixed time periods or, even better, traffic actuated. These lane-assignment strategies should be strengthened by signs and regulations. Detectors should be used to sense the position of the back of the queue and monitor system performance, and VMS's to display the current assignment and lane-changing restrictions. Video tracking fines and/or the exchange of money may be used to detect illegal lane-changes.

III. Problem Definition

The reasonably good expected effect of VMS in the study area excited the researcher to use VMS technology in solving one of the bad practices in the area. The existing fixed pavement marking at intersections is expected to be less efficient in the major change of demand. At one time (afternoon time) drivers will use left and straight lanes to turn left at high left demand. While at another time (morning time) the majority of the traffic is straight, so drivers will use only the left lane to turn left. The application of dynamic changing in lane usage in the different peak periods is expected to have significant effect in enhancing the movement of vehicles.

IV. Methodology

The goal of dynamic lane changing strategy is to reduce the conflict of lane-changing maneuvers by clearly defining turning lanes. This paper examined and modeled the new possible application of VMS on dynamic lane usage concept using ARENA simulation software. The data was collected on a signalized intersection in Al-Khobar City in Suadi Arabia, see map 1 below.

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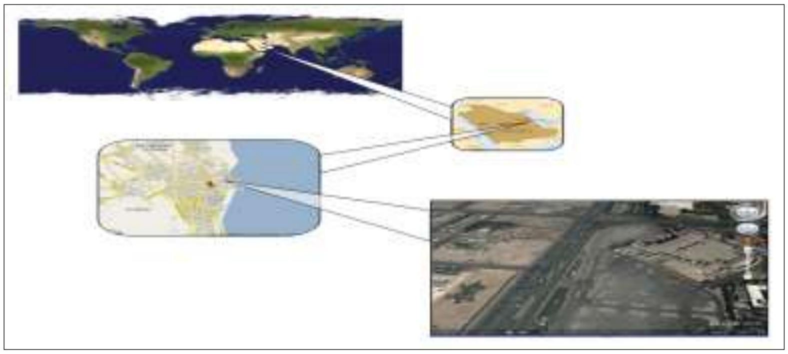

Map 1. Study area (Prince Faisal Road).

The concept was tested in one direction with two lanes at this intersection. The current situation (pavement marking) at such approach is that the right lane is assigned for drivers who intend to move through, and the left lane is shared between through and left movements at either AM or PM peak periods, as shown in Figure 1.

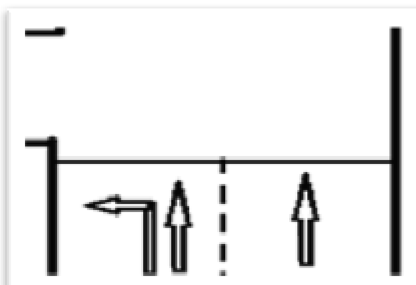

Figure 1. Current fixed pavement marking at AM and PM periods.

From the field observation, it was noticed that drivers usually position their vehicles in the shorter queue lane even if it is designed for the other movement. This situation is clearly noticed in Saudi Arabia intersections. Such behavior is expected to cause more delay, confusion, and accidents. It was noticed that during peak periods, the proportion of traffic on each lane is approximately what Figure 2 indicates.

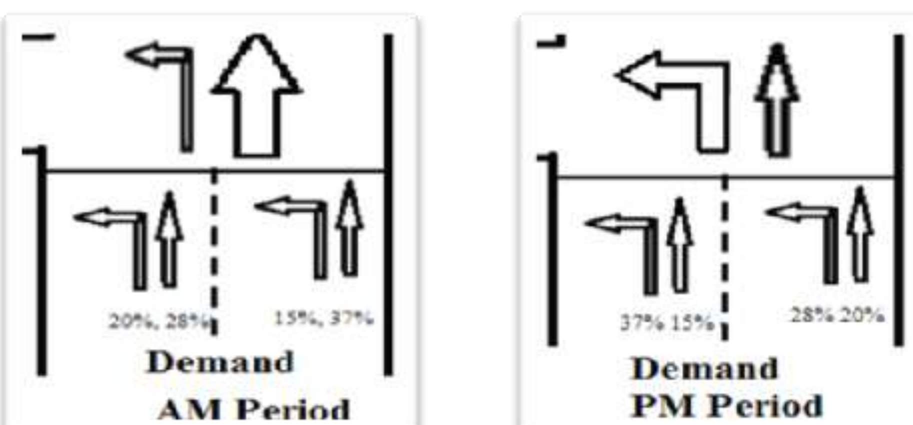

Figure 2. Current traffic percentage at AM and PM periods.

V. Results

A possible application of VMS to dynamically change the lane usage between AM and PM periods, in accordance with the traffic demand, is shown in Figure 3.

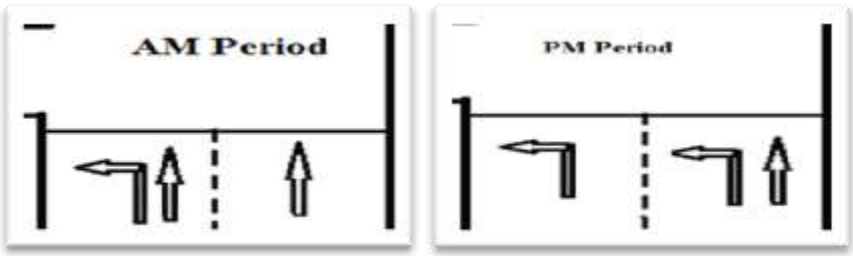

Figure 3. Proposed VMS lane usage at AM and PM periods.

It is expected that activating the VMS board before such signalized intersection and advising drivers on each lane usage will have the 8% response from the drivers that was found from the study. This means that the 15% will be reduced to 7%. And keeping in mind that drivers will position their vehicles in the shorter queue lane, it is expected that the same 8% will be shifted from the left to the right lane in the AM period and from the right to the left lane in the PM period, as shown in Figure 4.

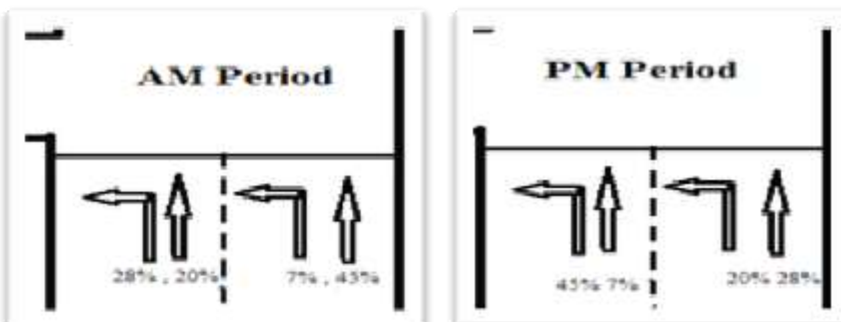

Figure 4. VMS impact on traffic percentage at AM and PM periods.

In case the VMS is used with some kind of enforcement at the intersection, forcing the drivers to follow the displayed VMS message, the traffic percentage during AM and PM peak hour can be presented as shown in Figure 5.

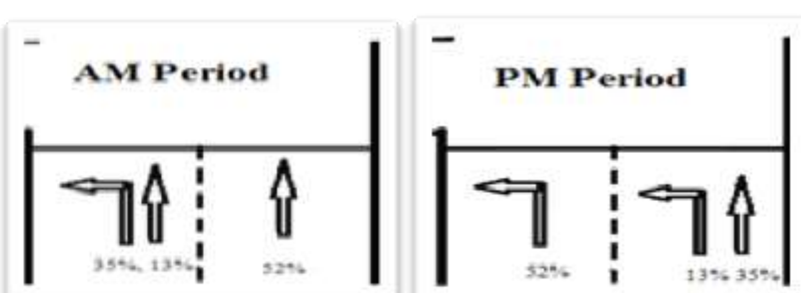

Figure 5. Traffic percentage at AM and PM periods using VMS with enforcement.

The above three situations were evaluated using ARENA simulation software. Arena is an easy-to-use, powerful tool that allows the user to create and run experiments on models of any systems. Arena software provides the maximum flexibility and breadth of application coverage to model any desired level of detail and complexity. It provides an intuitive, flowchart-style environment for building an "as is" model of the process by adding real-world data. Changes can be made to the model to capture the possible scenarios to be investigated, and compare the results to find the best "to be" solution.

The comparison includes the effect of the current local drivers' behavior, VMS message, and achieving fully controlled situation in both AM and PM peak periods. The results are summarized in Tables 1 and 2.

Table I. Dynamic lane usage evaluation at AM peak period.

Measure (sec/veh) / Situation		Current	With VMS	Enforcement
Average time spent in the system		0.182 (4.87)*	0.177 (4.23)	0.173 (3.94)
Average waiting time in the queue	**Right lane**	0.204 (3.87)	0.188 (2.96)	0.183 (2.88)
	Left lane	0.158 (3.60)	0.167 (3.23)	0.162 (2.74)

* ( ) Maximum time.

Table II. Dynamic lane usage evaluation at PM peak period.

Measure (sec/veh) / Situation		Current	With VMS	Enforcement
Average time spent in the system		0.176 (3.78)*	0.174 (4.23)	0.172 (4.23)
Average waiting time in the queue	**Right lane**	0.175 (2.78)	0.161 (3.21)	0.156 (2.94)
	Left lane	0.176 (2.55)	0.186 (3.23)	0.189 (3.23)

* ( ) Maximum time.

Tables 1 and 2 clearly indicate that the total traffic and queue time were enhanced (reduced) in both peak periods due to VMS usage, and it could be further enhanced if this usage is covered with some kind of enforcement.

VI. Conclusion

It is known that when a vehicle cut a queue in a high flow situation it will cause a temporary queue in the vehicle's original lane because of its deceleration maneuver. And if the lane-changing vehicle forces its way into its destination lane, the vehicles in this lane may have to decelerate suddenly. As a result, the discharge flow across both lanes, downstream of the lane-change, is reduced. In addition, that sudden lane-changing maneuvers create a safety hazard.

It should be clear that lane-assignment and lane changing strategies can be implemented with existing technology, if properly applied. VMS's should be used to display the current assignment and lane-changing restrictions. video tracking may be used to detect illegal lane-changes and issue fines. Finally, it was clear that the possibility of using VMS as a tool for dynamically lane assignment at signalized intersection 'which was indicated through ARENA simulation' proved to be quite promising.

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