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EFFECTIVENESS OF VARIABLE MESSAGE SIGNS IN IMPROVING THE ROAD NETWORK THROUGH ROUTE GUIDANCE

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ABSTRACT

Variable Message Signs (VMS) are a means of providing valuable information to roadway users and enhancing the performance of the road network. The main objective of this research was to analyze the effectiveness of the use of VMS in improving the efficiency of the road network. This was implemented through a number of case studies under different conditions and different designs of the VMS. As this is a unique traffic guidance method to Egypt, the different factors that may affect the effectiveness of the sign to divert drivers was studied to fully understand the benefits of implementing VMS in Egypt. Traffic data was collected from five sites which are located in Giza Governorate, Egypt. At each location, the driver had the choice of two alternative routes leading to the same destination. The VMS informed the drivers that one of these routes was congested and to use an alternative route. Three different sign types were applied to identify the most effective type of VMS on drivers in Egypt. The most effective sign type was identified during the pilot study and used in the remaining sites. For each site, Traffic counts for each route was recorded for twenty minutes without the VMS and twenty minutes with the VMS applied to obtain the diversion rate of drivers Average travel times for 30 vehicles and queue lengths were also recorded before and after the application of the VMS and Queue lengths were also recorded before and after applying the VMS.

Keywords: Variable Message Signs, Route guidance, Performance measures

1. INTRODUCTION

Variable Message Signs (VMS) have been implemented since 1960 in the United States of America and are largely deployed on freeways, highways and in work zones throughout the world. Variable Message Signs (VMS) are traffic control devices used to provide motorist en-route traveler information. They are commonly installed on full-span overhead sign bridges, post-mounted on roadway shoulders, and overhead cantilever structures. The information is most often displayed in real-time and can be controlled either from remote centralized location or locally at the site. Traveler information displayed on VMS may be generated as a result of a planned or unplanned event, which is programmed or scheduled by operations personnel. Variable message signs are commonly used to warn of traffic congestion, accidents, incidents, roadwork zones, or speed limits on a specific segment of the network. The VMS may guide vehicles to alternative routes due to congestion, limit travel speed, inform of incidents or traffic conditions. While there are many different types of VMS, they can be placed into three major functional categories based on how the sign messages are illuminated: light reflecting; light emitting; and hybrid (Dudek, 1997).

VMS have recently been implemented in Egypt near the Down Town district of Cairo, Egypt to inform motorists of parking vacancies in the Tahrir Garage and the bus routes and numbers to and from the Tahrir Garage. The VMS has not been applied to give route guidance to travelers. Due to the high congestion in Egypt, VMS have large potential to improve the performance of the Egyptian road network. The intertwining nature of the road network in Egypt creates multiple routes the road user may choose to take leading to the same destination. This provides a suitable environment for the application of VMS.

The mountable version or portable version of the VMS are used in areas where the permanent VMS are not available. Portable VMS are used in areas where traffic patterns are temporary and the high cost of a permanent VMS is not needed. These areas are usually next to work zones, during the occurrence of a natural disaster, unusual traffic congestions, or traffic management for special events. The messages displayed on the sign can be programmed locally on the unit's control panel, or units equipped with a cellular modem can be programmed remotely via computer or phone. Trailer-mounted VMS can be equipped with radar, cameras, and other sensing devices as part of a smart work zone deployment.

2. BACKGROUND STUDIES

Many form of technologies have been developed for Variable Message Signs as flip disk, light emitted diode (LED), Fiber optic and hybrid. Each one of these technologies provide messages in different patterns and textures. Some technologies may appear brighter and clearer than others and easier for drivers to see. The visibility of fiber optics appear to be better and more visible then the bulb matrix unit or the LED technology (Hoffman, 1995). Jenkins (1991), Upchurch, et al. (1992), and Garvey and Mace (1996) evaluated the relative legibility of various VMS technologies and found that, in general, VMS that used either light emitting or a combination of light emitting and light reflecting technologies (hybrids) outperformed light reflecting technologies, especially at night.

The message given to drivers on the VMS directly affects the effectiveness of VMS on driver’s behaviour and diversion rates. Since the VMS message can be illustrated in many forms, studies have been done to assume the most effective VMS message. Er-huia et al. (2013) studied the graphical representation of a hazard or specific route guidance through the VMS. Graphic information can be observed and identified further in distance then text information and the graphical information is not limited to language limits as the same sign can be used by different countries. Different graphical expression of the Variable Message Signs have significant differences in the diversion rates and drivers response. To be effective, a VMS must communicate a meaningful message that motorists can read and comprehend within a very short time period." (Ullman et al. 2005). This means that the sign should include the problem, its location and any action the driver may be able to take to avoid the problem. The message should also be as short as possible without becoming confusing, incomplete, or using improper abbreviations. Generic phrases should also be avoided since they can be applied across many different scenarios and do not provide much value to motorists. Generic messages can cause VMS to lose effectiveness with the motorists" since they lack specificity that the driver needs to make important decisions (Ullman et al. 2005).

It is expected that by providing real-time information on certain events to motorists, VMS can improve vehicles' route selection, reduce travel time, mitigate the severity and duration of incidents and improve the performance of the transportation network. S.Peeta et al. conducted bot SP and RP surveys to examine driver’s response to traffic information from VMS and found a large difference in the outcomes. These differences are mainly from the different characteristics of each driver. S.Peeta et al. considered the data from internet survey was more likely to be influenced by the VMS since the questioners were more technology aware and more likely to be affected by such technology. Fifty three percent of drivers asked in a SP questionnaire conducted by Jorge L Ramos et al. would respond to route guidance and divert from their current route if the expected delay on the current route was at least 10 minutes. Khattak et al. (1993) found that the effect of diversion can be increased by offering precise information on the location of congested sections. Location information seemed to be key in supporting decisions about diverting and returning (or not returning) to the original route. Anticipating the delay drivers are expected to face is important and presenting it to the driver is crucial in affecting driver’s decision to divert. This demands detailed information on traffic conditions and, in the case of incidents, knowledge of the nature of the incident and the action to clear it is crucial. Khattak et al. (1993) also found that in order for ATIS to be affective to a large spectrum of drivers, customization of the information is important. In particular, the system should allow users to choose from various routing suggestions. The driver should be able to select preferences for diverting and returning, or no diversion. Drivers should be able to select route planning criteria which reflect their preferences (facility types to seek out r avoid, simplicity versus speed, etc.). Displays should also be customized so that individuals can chose from audio, map based, text or icon based displays according to their abilities and preferences. This aspect of Khattabs research will have the most effect on the effectiveness of the VMS in Egypt as there are diverse preferences to Egyptian drivers. Lei Zhang and David Levinson (2008) found the data provided by ATIS is very valuable to drivers to the extent that they would pay for the information. Based on field experience stated preference surveys, regression models, and discrete choice models drivers are willing to pay no more than $1/trip for pretrip travel-time information, although the perceived value of information varies by trip purposes and route attributes.

3. RESEARCH OBJECTIVES

Determining the effectiveness of the VMS on drivers and its effect in improving the performance of the road network is an important issue for determining the possibility of reducing traffic congestion through new technologies as the VMS. Variable Message Signs are defined in the Variable Message Sign Operations as "programmable traffic control devices that can usually display any combination of characters to present messages to motorists." VMS are one of the most effective means of delivering real-time traffic data to the motorist. This real time information subsequently leads to the improvement of the road network and reduces congestion.

The lack of real time traffic information results in greater traffic congestions since the traffic distribution is not optimized. Moreover, motorists are not aware of certain incidents that may have occurred leading to less efficiency in the road network or may even cause additional incidents. It may also increase the probability of collisions.

The road network in the Greater Cairo Region (GCR) is characterized by being extremely congested especially during peak hours. There is a need for traffic management measures such as the use of road guidance in the form of VMS to relief such congested conditions and improve the traffic performance. To date, the effect of VMS on driver's behavior and the capability of VMS in improving the performance of the Egyptian road network (specifically the GCR) through traffic guidance has not been investigated although it is expected to provide for a means to reduce congestion on the extremely congested road network Therefore there is a need to research the efficiency of applying VMS to give real time traffic information to motorists. In addition, the type of VMS that will induce the largest diversion rates from one route to an alternate, less congested, route was investigated. Therefore, the main objective of this research was to statistically analyze data received from the field tests to properly assess the effect of the VMS on the Road Network and congestion. Another important objective was to obtain the most effective sign content applicable on Egyptian roads.

To realize the main objective, five sites were chosen for the study in Giza City (one of the three cities of the GCR). Three different characteristics of the road network were obtained from street cameras provided by the Giza Traffic Department. First, two hour video recordings of the links that were previously chosen were obtained from the Giza Traffic Department. These two hour intervals were coordinated with the team of experts at the Giza Traffic Department to focus on the links required and the video stream recorded at the two hour interval in which the experiment took place. Second, these recordings were thoroughly analyzed to obtain the traffic counts for each link at each location. The traffic counts before and after applying the VMS shows the diversion rate and the vulnerability of a driver to use an alternate route when given route guidance. The travel times of thirty vehicles from their origin, the location of the VMS, to the end of the link, where the congestion ends, is also obtained through the recordings. The average travel time for the link in each location is calculated from the thirty travel times. The average travel time is obtained for the two route options, the congested route and the alternative route which the motorist is guided to by the VMS.

More specifically, the study was undertaken with the following objectives:

- Calculating diversion rate of drivers from their original route to another less congested route after receiving route guidance information from the VMS.
- Studying the potentiality of the VMS to improve the road network performance through providing route guidance information to motorists.
- Defining the most effective method of delivering traffic information through the VMS since there are many factors that may affect drivers behaviour that are specific and unique to drivers in Egypt.

It is important to mention that the objective of the study is to ensure that the VMS is an effective means of improving the road network in Egypt before applying any VMS due to the high cost of permanent Variable Message Signs.

The scope of this research is to show the effect of applying a VMS at the location where the driver takes the decision on which route will be taken. The diversion rate is calculated to define the optimum sign design. This is done by applying the VMS for twenty minutes and removing the VMS for another twenty minute period. This process is repeated for three different sign types. The assumption is made that the traffic volume will remain the same for both twenty minute periods and this is why the traffic counts where chosen for a short period of time.

4. DATA COLLECTION PROCESS

4.1 Site Selection

The scope of this paper focuses on studying the influence of VMS on diversion rates which has a direct effect on the efficiency of the road network. Five locations in the Giza governorate were selected to achieve the objectives as shown in Figure 1 and described in Table 1.

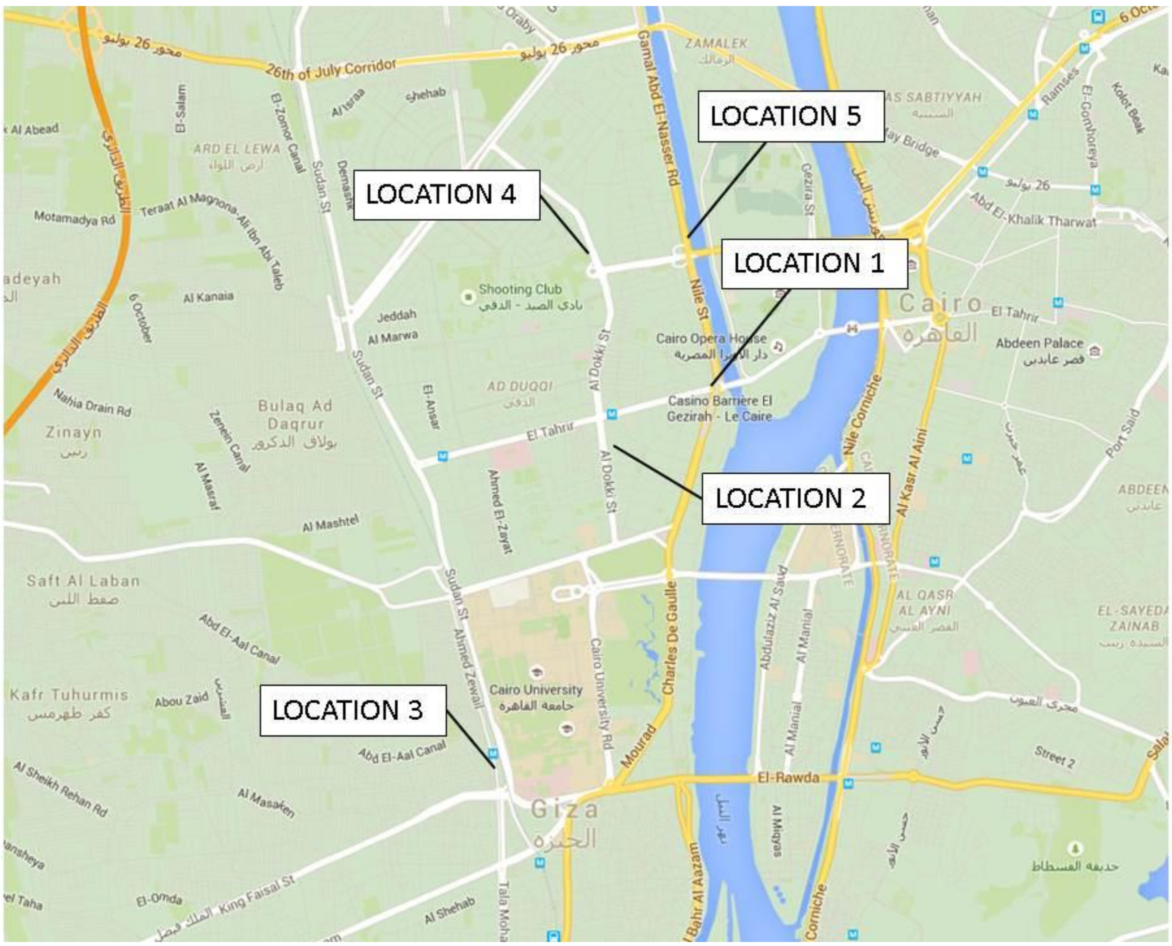

Figure 1: Map of Giza Governorate with Site Locations.

Table 1: Description of Study Sites.

Site No.	Site Description
1	Galaa Square: Located at Kornish El Nile Road. The traffic entering the square chooses between alternative routes to reach Giza square. This was also the location of the Pilot Study.
2	Dokki Bridge: Located on Dokki Street leading motorists to AL-Batal Street. Traffic coming from the Giza district traveling towards the Mohandseen district either choose to use the Dokki Bridge or Tahrir and Kornesh Street.
3	Faisal Bridge: Located at the end of Sudan Street leading motorists to Faisal Street. Motorists travelling from the Dokki District travelling to the Haram district choose between Faisal Bridge or Haram Street.
4	6th of October Bridge at Albatal Street: Located on Al-Batal street and leads motorists coming from Dokki District to the Cairo Governorate. Motorists travelling to the Cairo Governorate choose between the 6th October bridge or Tahrir Street.
5	6th of October Bridge at Kornish ElNile Street: Located on Kornish ElNile Street and leads motorists coming from Agouza District to the Cairo Governorate. Motorists travelling to the Cairo Governorate choose between the 6th of October Bridge or Galaa Square.

There were several constraints in choosing suitable locations to apply the VMS such as:

1. Suitable location for placing the portable VMS
2. Locations where traffic CCTV cameras are already available
3. Locations where drivers have an alternative route leading to the same destination with very similar distances
4. Decision distance
5. Locations where congestion may take place in one of the two routes to be able to divert traffic to the alternative route

4.2 VMS Message Design

In order to recognize the effectiveness of the message shown on the VMS on driver's route choice, it is essential to display various messages with words and signs since there are many factors that affect drivers' behaviour in Egypt. Each Message should be analyzed separately in order to recognize the optimal sign message. The programmable VMS is designed on the Powerled software and is changed on site by means of a flash drive.

Since this study concerns the effect of route guidance through VMS on the road network, the information provided to motorists was chosen to be congestion. The VMS sign must be as short as possible as not to confuse the driver (Ullman, Dudek, and Ullman 2005). Short messages are used to give the motorist the information needed to make the decision on the route used. The information should not be vague or misleading and should be read in a short amount of time. Based on this information three sign types were chosen to define the most effective VMS message: VMS (Type 1), VMS (Type 2), and VMS (Type 3) as shown in Figure 2. VMS (Type 1) was designed such as to simply inform drivers to take another route. VMS (Type 2) had more traffic information stating which route was congested and the alternative route, and VMS (Type 3) was a mixture of texts and figures informing drivers to choose another route due to congestion ahead.

VMS (Type 1) VMS (Type 2) VMS (Type 3)

Figure 2. The Different VMS Types Used

4.3 Research Methodology

Traffic characteristics that were determined in the field were queue lengths, journey times, average travel speeds and diversion rates. The queue lengths were observed for the first link after the VMS in both the congested route and the alternative route by means of a manual count and through the traffic department street cameras. Journey times for travelers from the VMS to the nearest destination was also observed by means of a test car deployed starting at the location of the VMS before and applied the VMS was applied in both routes . Average travel speeds were obtained by measuring the distance in the field from the VMS to the destination and dividing it by the average travel time. Diversion rates were obtained by the analysis of the traffic data traffic counts in both routes were before and after applying the VMS thus providing the diversion rates.

For each site, traffic data was collected for two hours for the alternative routes that the motorist may take after observing and receiving the traffic information from the VMS. The collected traffic data included the traffic counts for the alternative routes and the video recordings of the first link of the network reaching from the VMS to the first intersection. At each site, the data collection period was divided into 20-minutes intervals, such that the VMS was not applied in the first interval, then applied in the second interval. This cycle was repeated for the remaining four periods with the different VMS Types The main assumption was that the traffic volumes on the two alternative routes were constant in the two consecutive twenty - minute intervals for comparison purpose.

5. DATA ANALYSIS AND RESULTS

In order to achieve the research objectives, field data collection was performed in the form of street recordings provided by the Giza Traffic Department and manual traffic counts to calibrate and model the effect of the VMS in improving the Egyptian road network through route guidance. The next step was to analyze the collected data. Analysis of data was a process of inspecting, cleaning, transforming, and modeling the collected data. Therefore, this section presents the method used for the diversion rates of motorists from their original route to the advised alternative route. In addition, it introduces the method used to obtain road network factors before and after applying the VMS to provide traffic information and route guidance to motorists. It provides the statistical analysis to properly analyze the effectiveness of the VMS on motorists. The impact of the different sign messages is provided to reach the optimal sign message.

5.1 Diversion Rate Calculation

Calculating the diversion rates of motorists from their original route to the alternative suggested route is essential to analyze the effectiveness of each message delivered to the motorists. Many studies have been performed to determine the most effective VMS message but limited studies have been done on Egyptian motorists. Equation 1 shows how the diversion rates were calculated. Table 2 lists the diversion rates for the five locations and the field experiment.

[1] $$DR_{O,A} = \frac{V_1 - V_2}{V_t}$$

$DR_{O,A}$ = Diversion rate for Original Route or the Alternative Route;
V_1 = Traffic volume for the first 20 minute period while the VMS is off;
V_2 = Traffic volume for the second 20 minute period while the VMS is on; V_t = the total traffic volume for the 40 minute period.

Table 3: Diversion Rates for Each VMS Type

Location	VMS Type		
	1	2	3
Pilot	7.0	5.4	11.0
1	9.0	7.0	11.0
2	10.6	6.5	11.9
3	13.4	10.3	9.1
4	9.6	13.2	6.1
5	11.6	8.7	16.8

5.2 Estimation of Measure of effectiveness to assess the benefit of VMS on the road network

A before and after study was conducted to evaluate the improvement of performance of the network after applying the VMS. The benefits of VMS are determined in terms of travel time saving, queue length reductions and increase in average travel speeds

5.2.1 Measuring the Effectiveness of the VMS on Travel Time Savings

One of the main objectives of the VMS is to divert traffic flow due to a certain incident, in our case congestion, and to increase the effective capacity of the freeway during the time of these incidents by encouraging vehicles to take alternative routes. Therefore, the travel time saving for motorists is one of chief benefits of VMS systems.

Travel time saving can be measured as the difference of travel time before and after applying the VMS on the link of the network after the VMS is applied. The overhead street recordings provided by the Giza Traffic Department was used to obtain the travel times of 30 vehicles and the average of these vehicles. The traffic volumes were recorded for the congested route and for the alternative route for the 40 minute cycle. The travel times for thirty vehicles before and after the VMS was applied was recorded and the average taken from these recorded travel times observed in Table 4.

Table 4: Key Performance Index Table

Site No. and Description		Journey Distance (km)	Average Travel Times Before VMS (seconds)	Average Travel Times After VMS (seconds)	Difference in Average Travel Times (%)	Difference in Queue Length (%)	Difference in Average Speed (%)
Pilot	Congested Route	4.24	180	130	-16%	-17.65%	+16.67%
	Alternative Route	3.54	40	44	+4.75%	0	-4.60%
1	Congested Route	4.24	220	160	-15.80%	-16.13%	+15.79%
	Alternative Route	3.54	46	52	+6.11%	0	-4.76%
2	Congested Route	3.54	1156	915	-11.64%	-10.33	+12.50%
	Alternative Route	3.30	855	966	+6.10%	0	-3.85%
3	Congested Route	1.28	780	603	-12.80%	-10.64	+20.00%
	Alternative Route	1.35	342	404	+8.30%	0	-5.13%
4	Congested Route	2.74	1320	1010	-13.30%	-17.05	+15.38%
	Alternative Route	3.40	760	877	+7.14%	0	-3.37%
5	Congested Route	2.13	1066	770	-16.12%	-8.33%	+13.03%
	Alternative Route	2.53	540	616	+6.57%	0	-4.65%

The average travel times was calculated in two sample populations with each sample consisting of the travel times of 30 vehicles starting from the location of the VMS up to the first exit off the link. The average of means between the two samples is analysed by using the independent sample T-Test. The analysis has been taken carried out by means of the SPSS software and the output shown in Table 5.

Table 5: T-test for Equality of Means for effect of VMS on Travel Time of Each Site

Site No.	Levene's Test for Equality of Variances		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
	F	Sig.						Lower	Upper
Pilot	10.209	.002	8.387	40.641	.000	63.500	7.572	48.330	78.656
1	.705	.405	7.138	58	.000	49.900	6.991	35.906	63.894
2	5.001	.029	4.442	53.880	.000	111.767	25.159	61.405	162.128
3	2.263	.138	5.910	58	.000	107.300	18.155	70.959	143.641
4	.148	.702	2.546	58	.014	111.900	43.945	23.934	199.866
5	3.550	.065	3.174	58	.002	108.200	34.095	39.952	176.448

Figures 4 through 8 illustrate the statistical analysis of the sampled 30 vehicles travel speeds through box plots. The means and variances are illustrated on these figures.

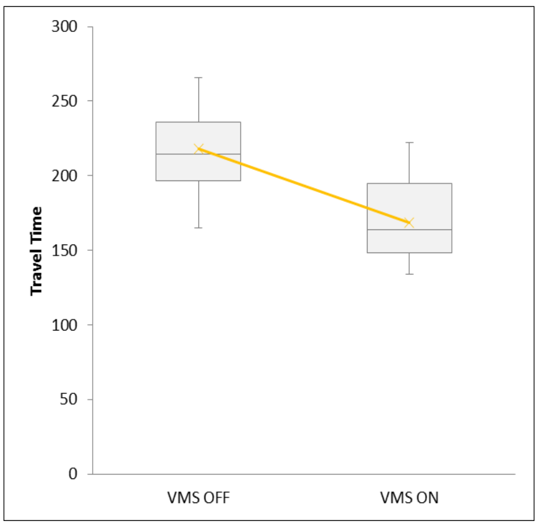

Figure 4: Box Plot of Location 1

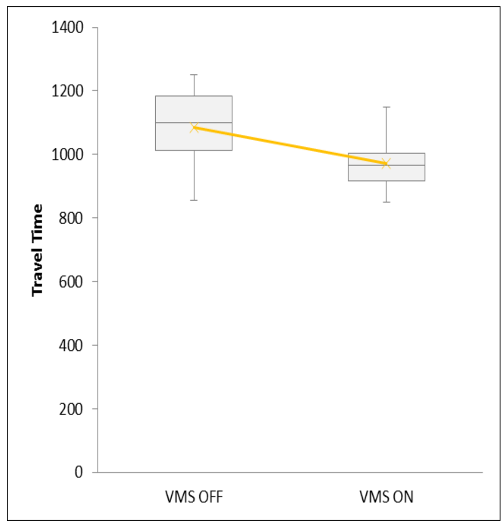

Figure 5: Box Plot of Location 2

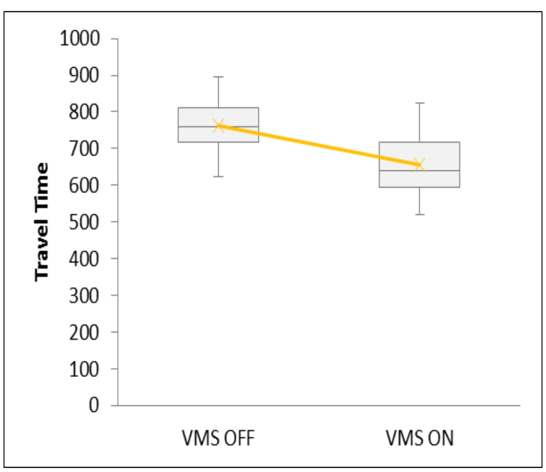

Figure 6: Box Plot of Location 3

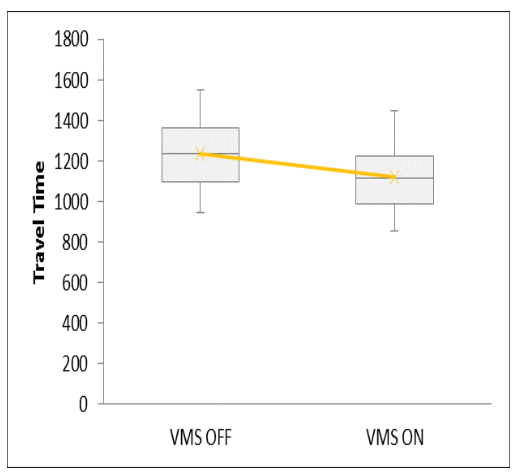

Figure 7: Box Plot of Location 4

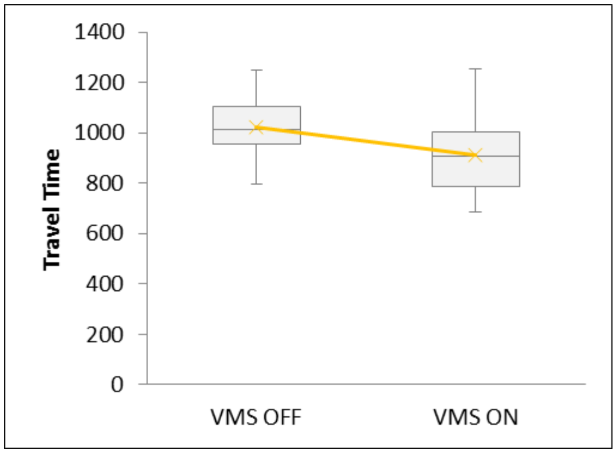

Figure 8: Box Plot of Location 5

6. CONCLUSIONS

The main objective of this paper was to study the effect of VMS on diversion rates and the effect on the roadway network. This is important in improving the road network in areas of congestion or areas were real time traffic information is needed.

The results show that VMS (Type 3), which was a mix between traffic information provided by text and figures, gave the highest response rate from drivers and the highest rate of diversion. The diversion rates ranged from 5% using text only (VMS (Type 1)) to 12% using the mixture of text and figures (VMS (Type 3). The statistical analysis of the thirty sampled vehicle showed a statically significant difference between the average travel times before and after applying the VMS. In some locations the comfort of travel also increased by reducing the variances in the travel times before and after applying the VMS.

Observed average travel times, queue lengths and average speeds were the parameters used to measure the effectiveness of the VMS in improving the road network. The results of the road network parameters were all improved on the congested routes. The effect of the VMS on the alternative route was minimal and no queues were observed after diverting traffic to these alternative routes.

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