12-2012

Evaluation of the Effectiveness of Portable Variable Message Signs in Improving Safety for Motorists and Workers at Construction Zones in Abu Dhabi

Khalid Ismail Al-Zoubi

جامعة الإمارات العربية المتحدة
United Arab Emirates University

UAEU College of Engineering

UNITED ARAB EMIRATES UNIVERSITY
COLLEGE OF ENGINEERING

Evaluation of the Effectiveness of Portable Variable Message Signs in Improving Safety for Motorists and Workers at Construction Zones in Abu Dhabi

A Thesis

By

Khalid Ismail Al-Zoubi

Department of Civil and Environmental Engineering

Submitted in partial fulfillment of the requirements

for the award of degree of

Master of Science in Civil Engineering

December 2012

جامعة الإمارات العربية المتحدة
United Arab Emirates University

UAEU College of Engineering

UNITED ARAB EMIRATES UNIVERSITY
COLLEGE OF ENGINEERING

Evaluation of the Effectiveness of Portable Variable Message Signs in Improving Safety for Motorists and Workers at Construction Zones in Abu Dhabi

A Thesis

By

Khalid Ismail Al-Zoubi

Department of Civil and Environmental Engineering

Submitted in partial fulfillment of the requirements

for the award of degree of

Master of Science in Civil Engineering

December 2012

DECLARATION

The undersigned have examined the thesis entitled '**Evaluation of Effectiveness of Portable Variable Message Signs in Improving Safety for Motorists and Workers at Construction Zones in Abu Dhabi**' presented by **Khalid Ismail Al-Zoubi**, a candidate for the degree of **Master of Science in Civil Engineering** and hereby certify that it is worthy of acceptance.

Examination Committee

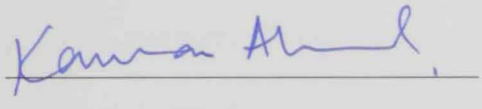
Dr. William C. Taylor (External Examiner)

Emeritus Professor
Department of Civil Engineering
Michigan State University
3566 Engineering Building
East Lansing, MI 48824

Dr. Yasser Hawas (Internal Examiner)

Professor
Civil & Environmental Engineering Department
College of Engineering
United Arab Emirates University
Al-Ain, P.O Box 17555, UAE

Dr. Kamran Ahmed (Principle Supervisor)



Associate Professor
Civil & Environmental Engineering Department
College of Engineering
United Arab Emirates University
Al-Ain, P.O Box 17555, UAE

Dr. Essam Zaneldin (Co-Advisor)

Associate Professor
Civil & Environmental Engineering Department
College of Engineering
United Arab Emirates University
Al-Ain, P.O Box 17555, UAE

ABSTRACT

In March 2008, a single accident resulted in three people being killed and nearly 350 injured in a horrific crash involving over 60 vehicles on the Abu Dhabi-Dubai highway near Ghantoot. The cause of this crash was attributed to failure by motorists to adhere to severe weather conditions (fog). In response to the increasing number of accidents on Abu Dhabi roads, the Abu Dhabi Department of Transport (DoT) has deployed approximately 40 portable Variable Message Signs (PVMSs) throughout the main DOT's highway network as one of the strategies to control driver behavior and to improve road safety. The objective of these PVMSs is to provide drivers with adequate warnings; especially during severe weather conditions (e.g., fog, dust, rain). They are also used within critical areas such as construction zones on the highway, at school crossings and during major events so as to minimize the chances of accidents.

The aim of the study was to evaluate the impact of PVMSs on road safety as well as their perceived satisfaction among road users. The effectiveness of PVMSs in Abu Dhabi has not yet been evaluated in this way the study adopted a longitudinal approach and involved the collection of vehicular speed, volume and classified data at three different highway sections. These covered one location close to a work-zone in Abu Dhabi with allowable speed limit of 100km/hr, another location on freeway with allowable speed limit of 140km/hr and one location on an arterial road with allowable speed limit of 120km/hr. Additionally, drivers and workers were interviewed in order to seek their perception on the use of PVMS.

Using descriptive and analytical statistical methods, the mean and 85th percentile speed differences before and after the deployment of PVMS were found not to be statistically significant at the study locations. At both urban and rural locations, PVMS was shown to have a minor impact in reducing highway speeds but it was found not to be statistically significant. The study showed that PVMSs were found to be effective, though statistically not significant (p-value > 0.005 at 95% confidence level), in reducing driver's speeds with about 1% on freeway and arterial roads. PVMSs are not significant statistically effective in reducing speeds at the work zones. Newly deployed PVMS at work zones confuse drivers especially when the posted speed limits are reduced gradually over a short span length. Further, the proportion of vehicles speeding excessively (i.e. vehicles traveling over the posted speed limit) was slightly decreased by the use of PVMS.

A significant number of road user's responses were positive and highly satisfied with the usefulness of PVMS as a tool to display the traffic information to drivers and to manage traffic safety at work zones. They also stated that PVMS is an effective tool in alerting drivers about the irregular traffic conditions and/or any incidents on the highway and within work zones. There were many comments on the current operation of the PVMS that are mainly on updating PVMS messages, messages shall be changed frequently, PVMS messages shall cover the benefit areas mentioned in the driver survey and more care shall be considered for PVMS as a communication tool with the roadways users in order to increase the convenience on PVMS.

In addition, surveys of road construction workers indicated that workers were aware of PVMS and considered PVMS to be the best tool available for traffic safety at work zones. Most of the road construction workers stated that they feel safer with the implementation

of the PVMS during night shifts. The main comment was on implementation of the PVMS which are mainly about; not common in most of the work zone areas, it should be implemented immediately over all work zones within Abu Dhabi, should be well maintained through the whole construction period and moved away until work zone is cleared. Increasing public awareness of the use of PVMS suggested being a common tool used at work zones.

Some recommendations can be drawn from the study. The operation of PVMS shall take more care from Department of Transportation and Ministry of Interior – Police Department. The PVMS messages should be updated regularly and be varied to accommodate a wider range of incident warnings to assist in accident reduction. In general, PVMS messages should also be displayed as symbols to cover the illiterate drivers and workers and non-English/Arabic speakers.

DEDICATION

To my Parents, Brothers, Sisters, and Wife, for their guidance, support, love and passion.

Without these things this research could not have been possible.

ACKNOWLEDGMENTS

I would like to express my deep gratitude to Dr. Kamran Ahmed as my advisor and committee chairman for his constant guidance and support in reviewing and revising my thesis. His assistance has been essential to the development of my thesis. I would like to thank Dr. Essam Zaneldin for his help in reviewing my thesis.

I would also like to thank the Faculty of Engineering and Department of Civil and Environmental Engineering for continuous support during this research work. I would also like to thank the Department of Transportation for their support and flexibility during the long months it has taken to research and write up this dissertation. Further, I have to recognize the support and encouragement provided by my parents, my wife, brothers and sisters.

Special thanks are also accorded to Mr. Abdullah Al Otaiba the Chairman of the Department of Transportation in Abu Dhabi, and Eng. Faisal Al Suwaidi, General Director of Main Roads Division, for their support in data collection stage.

My deepest gratitude is also extended to Keith Brown, Transportation principle engineer, for his technical support and guidance in writing this dissertation which were of a great value to this research.

Finally, I would like to acknowledge the inputs of those who assisted me in one way or the other towards the final realization of the goals of the entire master's program.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background

The road fatality rate in Abu Dhabi is one of the highest in the world. There was an increase in road accidents of 11% between 2009 and 2011 (HAAD, 2010; DoT, 2011). Fatal road accidents rose by 1.4% between 2009 and 2011, while the number of traffic injuries rose to 6,629 casualties in 2011. Road crashes accounted for 63% of all injury deaths in 2010 with more than half of all road fatalities within the 16-35 age group (HAAD, 2010). The main contributory factor to the high number of accidents in the UAE is driver behavior, with speeding emerging as the leading cause of accidents (DoT, 2011).

According to Abu Dhabi Police records, in March 2008, a single accident resulted in three people being killed and nearly 350 injured in a horrific crash involving over 60 vehicles on the Abu Dhabi-Dubai highway near Ghantoot (DoT, 2011). The cause of this crash was attributed to failure by motorists to adhere to severe weather conditions (fog). In response to the increasing number of accidents on Abu Dhabi roads, the Abu Dhabi Department of Transport (DoT) has deployed approximately 40 Portable Variable Message Signs (PVMSs) throughout the DOT's main highway network as one of the strategies to control driver behavior and to improve road safety. These strategies have been accompanied by other measures which include introducing tough penalties for violating traffic laws, and installing speed detection cameras on various roads. The objective of the PVMSs is to provide drivers with adequate warnings; especially during severe weather conditions (e.g., fog, dust, rain). They are also used within critical areas

such as construction zones on the highways, at school crossings and/or during major events for guidance in order to reduce the chances of accidents.

1.2 Problem Statement

While many strategies, including PVMSs, have been employed in many parts of the world to manage road accidents, their effectiveness has been shown to be varied. Importantly the effectiveness of the application of PVMSs on Abu Dhabi roads has not yet been evaluated. It is against this backdrop that the study intends to evaluate the effectiveness of PVMSs on improving traffic safety for motorists and construction workers at construction zones in Abu Dhabi.

1.3 Objective and Scope

This study intends to evaluate the impact of PVMSs on road safety and their perceived satisfaction among road users. The evaluation process will consist of three main tasks: 1) collecting before/after (or with/without PVMS) speed data at three different highway locations including one location close to a construction site on a highway; 2) Conducting driver satisfaction surveys at four petrol stations, located along roadways just after the locations of the installed PVMSs; and 3) Evaluating the impacts of PVMS on road safety and users, through a sample opinion survey and speed measurements. It is intended that the conclusions drawn from the study will form the basis for further future studies.

The specific objectives of this research are to assess the:

- Impact of the PVMS on operating speeds and drivers speeding behavior.
- Ease with which drivers notice, understand, and use PVMSs.

- Effectiveness of PVMSs on the safety at construction zones.
- Impact of PVMS on crash frequency and severity.
- User perceptions of safety in the overall context of the selected roadway segments.

1.4 Thesis Outline

This thesis report consists of 6 chapters including Appendices. Chapter 1 provides the study background, defines the study problems and the scope and objectives of this research while Chapter 2 contains the findings from a comprehensive review of the literature that is relevant to this study.

Chapter 3 provides the methodology followed in this research including the procedure, participants, data collection locations, methods used in analyzing collected data, and the equipment used in the data collection process Chapter 4 covers the overall detailed data collection of this study, which comprises vehicle speed data, available crash data and attitudinal survey data for both drivers and workers.

Chapter 5 provides the results of the data analysis and Chapter 6 provides conclusions and recommendations for further study.

Finally, the Appendices consist of detailed material considered pertinent to the body of the thesis (e.g., data collection correspondences, survey questioner, sample data analyses, etc.).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Variable Message Signs (VMS) represents a family of Intelligent Transportation Systems (ITS) tools that are used in communicating traffic information to motorists to keep them aware of prevailing roadway conditions as well as perform the function of displaying one of a number of messages as warranted by particular situations. The Federal Highway Administration (FHWA) defines VMS as a traffic control device that is capable of displaying a variety of messages to inform motorists of unusual and or unexpected roadway conditions that might affect drivers normal performances. They are designed to provide notification to motorists on traffic hazards, incidents, lane closure, road works, route guidance, emergency information, real time congestion levels, variable speed limits, as advertising tool for special events and weather related traffic conditions (John et al, 2010).

Abu Dhabi Department of Transportation highlights the various applications of Portable Variable Message Signs (PVMS) in providing drivers with advisory and warning messages under the following conditions (DoT, 2009). These include; None reoccurring congestion, Unplanned events, such as accidents, breakdown, emergency road works, spills, road conditions, and adverse weather conditions and Planned events, such as road construction, maintenance and/or Special events.

This Chapter provides a literature review of relevant previous research studies published between the year 2000 – 2012 whose aims have been to evaluate the effectiveness of Variable Message Signs (VMS) on driver behavior and attitude.

2.2 Application Areas of VMS

With technological advancements in Intelligent Transportation System tools (ITS), VMS are now gaining popularity in their potential of providing real time travel information and guidance to drivers under prevailing conditions to enable them make informed decisions along their trips. The main application areas of VMS include road accident management, speed management, congestion management, weather and road conditions information relay among others. The details of these application areas and studies that have done to determine their effectiveness is provided in the following sections.

2.2.1 Road Accidents Management

VMS find applications in road accidents management. Studies have been conducted elsewhere to determine the effectiveness of Variable Message Signs in reducing road crashes.

In Canada, Toronto, a real-time crash prediction model was developed to estimate crash potential based on short-term variation traffic flow characteristics related to variable speed limit (VSL) by Lee et al (2006). The relationship between the variation of traffic flow conditions that includes VSL installment and crash potential was identified using modeling techniques. The model simulated changes in traffic conditions as an effect of variable speed limit and combined with the crash prediction model for the evaluation of

control logics. Overall, the study investigated the effect of variable speed limit sign on the crash potential reduction and total travel time and the results indicated that variable speed limit could reduce crash potential by 5-17% by temporary reducing speed limit during risky traffic conditions when crash potential exceeded the pre-specified threshold.

Due to high accidents involving animals and vehicles in Montana in the United States, a study was commissioned to determine whether the use of VMS would effectively reduce these accidents (Hardy, Lee, and Al-Kaisy, 2006). Accordingly, two permanent and one portable variable message sign were installed as advisory system with posting a messages advising the drivers of the wildlife moving across at specific routes. The study found that wildlife advisory messages posted on permanent and portable VMS were effective in reducing average vehicle speeds, and that the advisory messages are more effective in reducing speeds during dark conditions. Additionally, the messages on the portable VMS were found to have a more significant impact on average speed than the messages on the permanent VMS.

In Norway, the variable message signs were evaluated in as part of the Norwegian Road Directorates programme "ITS on the road towards 2020" in order to determine the effect of six variable messages signs (VMS) on travel times, road safety and the environment Trondheim (Alen et al, 2011). The VMS messages displayed information on travel times, incidents and congestions and their impacts were investigated using simulations, user surveys and analysis of speed data. The road safety was investigated through how incident information were affecting the number of crashes in the entire road network using traffic simulation. The safety effects were estimated based on the effects of VMS

information on the total number of vehicle kilometers, traffic volumes, the number of vehicle kilometers of traffic re-routed to roads with a lower standard, speed and the number of vehicle kilometers in congestion. The results showed that none of these variables was found to change significantly, and in most scenarios the change is below 1%. The study concluded that the estimated network effects on safety are based on traffic simulations and are therefore uncertain. The general finding that crashes, especially fatal crashes, will increase is assumed to be realistic.

2.2.2 Congestion and Incident Management

VMS have found enormous applications in congestion and incident management. Their applications in incident management is gaining momentum and is a major step towards achieving the goals of ITS as motorists become aware of upcoming incident conditions and are thus given the opportunity to divert to alternate routes. They also warn motorists of significant delays or congestion on the roadway along their routes.

In Kuala Lumpur, assessment of impact of variable message sign on traffic surveillance was undertaken on MRR1 1 freeway to quantify effects of VMS on traffic condition (Arash and Othman, 2009). The study attempted to utilize traffic data from the MRR1 freeway and driver response to displayed messages of varying lengths and formatting. Results showed that usage of VMS reduces the average travel times by 19.7% and were successful in diversion works which resulted in road occupancy reduction by 5.3%. There was a significant reduction of travel times during incidences with presence of VMS. The study concluded that VMSs have no significant impact on gap (Queue) but occupancy comes down.

In France, the behavior of road users on VMS messages about travel time to avoid congestion was studied by Brigitte et al. (2007) in order to explain the reasoning behind why some drivers behave in a way and another don't. The study was conducted on an expressway of 37 km that circles Paris city. The traffic measurements and observations were not enough to understand the mental process involved in reading the messages before the driver takes any decisions and the types of reasoning drivers use when deciding whether to continue on or to leave a saturated route. Further interviewers with the driver-participants were conducted in such a way as to gather information on the choice of the automobile over of transportation, the most recent actual itinerary taken, evocation of the different routes taken and description of the way the VMS system works. The study concluded that most of drivers are no more likely to change their itinerary when the expressway is crowded. As a result, travel time information affects traffic congestion at the opposite of expected traffic state.

In China, where there are more than 160 VMS on urban expressway network in Beijing, an evaluation of variable message signs on urban expressway in Beijing on the east of Jimen Bridge was undertaken as a case study by Xi et al. (2009) in order to determine the impacts of VMS on reducing traffic congestion. The evaluation criterion of VMS was built by taking VMS characteristics into account which are; efficiency of transport system and capacity, mobility, safety, energy consumption and environmental costs and customer satisfaction. Three traffic flow detectors are chosen for traffic data source for without VMS for year 2006 and with VMS for year 2007. The traffic flow rate was analysed based on two sample t-test for with and without traffic flow. The results showed

that with VMS, there was a significantly increase in traffic flow rate. The congestion duration during the 2007 study period was less than that of date 2006, while slowness duration of date 2007 is larger than that of date 2006. VMS has a good effect on congestion relief. In conclusion, VMS has a good effect on congestion relief.

Another study in China on evaluation of the effects of VMS on Urban Traffic Network was undertaken in Beijing based on a simulation model and time-dependent traffic assignment model to illustrate the effects of the VMS (Shuyan and Wei, 2006). The "with and without" VMS evaluation process was based on a network level and user level considering both cases recurrent congestion and non-recurrent congestion. The results showed that even where VMS are not displayed on all links in the network, the user travel time and link service level can be improved at a network level. However, the VMS--displayed links contributes more improvement to the network performance, especially in situation of non-recurrent congestion.

During the Bejing Olympics, the traffic guidance by VMS achieved excellent results. The road condition dynamic and quantitative information which was released during the Olympics provided travelers with real-time road conditions and travel time of main Olympic lines. The Olympics traffic guidance VMS information system interfaced automatically or manually entered data from different sources to produce the information after having been processed by the system. The VMS information release system achieved state-of-art practice results and good application effects in the Olympics traffic security and daily traffic operations in Beijing. In conclusion, with the collection scale and level of the basic traffic information being continuously improved, the public-

oriented traffic information release service will be more popular and will also continuously generate a new demand, which leaves several problems to be deal with (Guan et al, 2009).

Similarly in Denmark – Copenhagen, Variable Message Signs supported by cameras have been used considerably to relay speed and information messages on major motorways and ring roads. Their usage has had positive results as they have successfully redirected traffic volumes during rush-hour along these routes (Copenhagen Plans Ahead, 2005).

2.2.3 Weather Condition Advisory

VMS are commonly used in displaying weather-related information that affects traffic flow. They find applications in advising motorists of severe weather or environmental conditions in the area, especially those requiring a change in the motorist's driving behavior.

The effectiveness of the application of VMS in providing weather related information such as fog, snow has been extensively tested in Europe. In London for example, a warning system for fog on motorways was discussed by Cooper and Sawyer (2005). The system automatically detects fog by detectors along the motorway. When the visibility is less than 250m the word "fog" is shown on the variable message signs at 0.8 to 2.2 km before the traffic encounters the detector. During periods of heavy fog extra warnings can be stated on signs at 1.8 to 3.8 km before the detectors. The vehicles speed data during fog were collected to measure the effectiveness of the system. Twelve variable message signs were chosen for evaluation of the entire three-lane sections of motorway and also

sufficiently far from intersections so that vehicles normally should be travelling with constant speed and without changing lanes. The before and after speed observations show a significant decrease in speed by an average of 2.9 km/hr.

In Finland, a field study aimed at evaluating the effects of Variable Message Signs for slippery road conditions on reported driver behavior was undertaken by Juha at el. (2000) using data collected from a combination of roadside and telephone interviews. The results showed that VMS reduced the average speed by 1-2 km/hr and the minimum headway between vehicles decreased the proportion of short headways. The study concluded that VMS do indeed have other effects, such as the refocusing of attention to seek cues on potential hazards, testing the slipperiness of the road and more careful passing behavior.

Other field studies in Finland aimed at investigating the effects of Variable Message Signs on driver behavior was carried by Rama and Kulmala (2000) as a before-and-after experiment at three test sites. The study was considering two variable message signs with subjects on a slippery road condition sign and a sign recommending the minimum headway between vehicles. The results showed that the slippery road condition sign reduced the average speed on slippery roads by 1-2 km/hr in addition to the decrease caused by the adverse road conditions. The minimum headway sign decreased the proportion headways shorter than 1.5s for cars in car-following situations, in addition to a speed reduction of 1 km/h.

In Saudi Arabia, the effectiveness of a fog warning system was investigated Al-Ghamdi (2005) when he tested the effectiveness of a system that included visibility sensors

detecting when hazardous conditions due to fog occurred, leading to automatic activation of a VMS posting an advisory speed limit. The system was installed on a 2 km section of a two-lane, rural highway. The data collection mainly included vehicle speed, volume, classification, time headway, time of day, and visibility distance. The results showed that the warning system did not lead to reduced speed variability, but mean speed throughout the experimental sections was reduced by about 6.5 km/h.

2.2.4 Speed Management and Enforcement

VMS do find applications in speed management and enforcement in many European cities. In United Kingdom, the effectiveness of VMS in reducing congestion through M25 road was studied by Domini Paulo et al (2010) on the M25 road anticlockwise between junction 28 and 27. The road didn't have a significant collision history but experienced regular, peak time congestion, when traffic volumes increased and speeds decreased to the point that flow breakdown occurred. The research was aimed whether VMS would improve the traffic congestion according to the monitored average vehicle speeds and traffic volumes passing through the installed five PVMS using combination PVMS, cameras, time management server and wireless general packet radio service communication. Under congested conditions, advisory 50mph limit displayed on PVMSs. The results showed that VMS helped in reducing congestion and minimized flow breakdown. Also, there was no injury collisions reported during the operational period.

Similarly, in United State, effectiveness of PVMS in reducing vehicle speeds was studies in rural highway work zones (Li et al, 2010). The field experiment was conducted on one-lane, two-way rural highway and the study had three different scenarios that

included: PCMS switched on with the message "Slow Down", PCMS switched off, but still visible and PMS removed from the road and out of sight. Speed measurement sensor systems were used from 9:00am to 5:00pm. The results for traffic volume of about 3,500 vehicles showed that PCMS was effective in reducing vehicle speeds significantly when PVMS turned on either than when PVMS turned off or absent. The vehicle speeds reductions were statistically significant by 7.6 km/hr, 5.3 km/hr and 3.1 km/hr for the studied cases when PVMS is turned on, PVMS turned off and absent of PVMS respectively. There was a weakness in the field experiments for this research project in that the without PCMS data were collected from other work zones located on the same road and with PCMS (On/off) data were collected from the study location.

Tay and De Barros (2010) tested two anti-speeding VMS messages 30 on driver behavior. In this study, a driver survey and speed survey were performed. The 31 study showed that the messages developed have only a relatively small albeit beneficial effect on driver attitudes and on-road traffic speed.

Cheo et al, (2009) investigated the, driver responses to VMS measured in terms of changes in speed and acceleration in Korea. The study was explored by using the individual vehicle trajectory data extracted from in-vehicle differential global position system (DGPS) which provide more accurate and readily available vehicle trajectories. The field experiment was conducted during off-peak periods and non-incident conditions to ensure that observed driver behavior was solely due to VMS effect. In total, 15 participants drove DGPS equipped vehicles through 14 VMS influences zones on tangent and near-tangent segments of the Olympic freeway where the speed limit is 80 km/hr, to

eliminate the effects of geometric conditions on driving performance. The study found that drivers tend to decrease their travel speed while reading and processing VMS messages, and increase speeds after they finish reading VMS messages. There were a statistical significant in the average speed and acceleration through VMS signs as concluded from the ANOVA test and density estimations.

On the other hand, in Norway, the effectiveness of VMS in rerouting traffic and possible impacts on safety were studied by investigating the effects of the VMS on route choice and on speed and breaking behavior (Erke et al, 2007). The study was conducted at two sites outside Oslo where VMS were permanently installed and displayed information about a closed road section downstream on the motorways and recommendations for alternative routes. Route choice, speed and breaking behavior were compared between vehicles approaching the VMS while they displayed messages and while they were left blank without message. The results of speed measurement for 3342 vehicles showed large speed reductions, and video observations showed that large proportions of vehicles braked while approaching the VMS.

2.2.5 Work Zone

VMS are now finding more application in traffic management in many construction sites in many parts of the world. These have been used to augment the traditional detour signage and the standard temporary work zone warning and regulatory signage.

In United States, a study was undertaken to provide a comprehensive review of the application of various intelligent portable traffic management systems (Fang and Clara,

2008). The study identified innovative technologies that have the potential to improve highway traffic operations. The study was based on conducting interviews with representatives from department of transportation in various states in USA and private industry regarding their experience with and knowledge of work zone and incident management deployment initiatives and innovative technologies. The study concluded that an effective management work zone activities and incidents are intended to enhance safety and operational efficiency for the traveling public and roadway workers. This can be accomplished through an information technology that includes ITS application, traffic data collection, data analysis, and traffic information dissemination.

Other field experiments were conducted in Kansas USA during the resurfacing of a two-lane highway (Finger et al, 2009). One PVMS (either activated with the text "Slow Down, Drive Safely", or not activated) and one temporary traffic sign showing the message "Road Work Ahead" were used. The results showed that; when the PVMS was turned on, the device reduced passenger vehicle speeds by 3.9 mph, truck vehicle speeds by 4.7 mph, and semitrailer vehicle speeds by 3.1 mph over a 500 foot distance. When PVMS was turned off, car vehicle speeds were reduced by 2.4 mph, truck vehicle speeds by 3.7 mph, and semitrailer vehicle speeds by 3.0 mph over a 500 foot distance. When temporary traffic sign (TTS), no PVMS, was on the road and the vehicle approaching the advance warning area, car vehicle speeds dropped by 5.2 mph, truck speeds by 2.8 mph, and semitrailer vehicle speeds by 5.0 mph over a 500 foot distance. The results showed that the VMS was effective in reducing passenger car and lorry speeds in one way two-

lane work zones. However, it was noted that the temporary traffic sign had a larger speed reducing effect on passenger cars and semitrailers than the activated VMS.

An evaluation of the effectiveness of variable advisory speed system (VASS) on queue mitigation in work zone was undertaken by Aaron et al, (2012) and was intended to perform a statistical analysis on pertinent performance data to evaluate VASS effectiveness on queue mitigation at a work zone on a freeway in Utah. The deployed system equipment consists of two VMSs and five microwave speed sensors that measured speed, volume, and occupancy for each of the lanes of traffic. The data collection consisted of before data and after switch on VMSs and activation of VASS system. The results showed that the VASS was effective on weekends during evening peak hours where there was a slowdown in the work zone approach. However, no consistent significance was seen on weekdays during the evening peak periods.

In United States, another study on evaluation of work zone design features including PVMS along a rural road in Massachusetts. The traffic data was collected over four months in a location where a full lane closure on a long-term bridge replacement project. The study found out that average speed drop was about 8.5mph after installing PVMS, while the speed change was negligible before and after the static signage. The study concluded that PVMS in advance of work zones is effective tool in reducing driver speeds (Heaslip et al, 2009).

In Denmark, the Danish Road Directorate has implemented different traffic management applications on motorways in order to improve traffic conditions during construction

work. When the impacts of the use of VMS in providing real-time traffic information at construction sites was investigated, the study showed that VMS had led to a slight decrease in driver speeds, with 78% of the motorists respected the fixed speed limit of 110 km/h before the construction started, but only 67% respected the variable speed limit of 80 km/h during construction (Wendelboe and Jens, 2008)

2.2.6 Other Applications

VMS also find application in many other areas including event management where advanced notice of a special event causing traffic or safety implications to travelers is often displayed on portable variable message signs / variable message signs. This allows drivers to avoid congested areas during the scheduled event. Additionally, traffic control messages may be displayed to guide vehicles and lessen the severity of congestion. In the United States, Birdsall (2008) in a study commissioned by the Federal Highways Agency did an inquiry into the contribution of VMS to driver distraction. Particularly, he studied the impacts of information displayed on commercial electronic VMS digital billboards such as wanted criminals' photos, missing children or advising motorists of emergencies ahead on drivers as well as pedestrians' attentions. The study found out that the VMS signs have no considerable impacts on drivers' visual impairments.

CHAPTER 3: STUDY METHODOLOGY AND DATA COLLECTION

3.1 Introduction

The aim of the study was to evaluate both the effectiveness of PVMSs on road safety and their acceptance. This chapter presents the methodology adopted for the study.

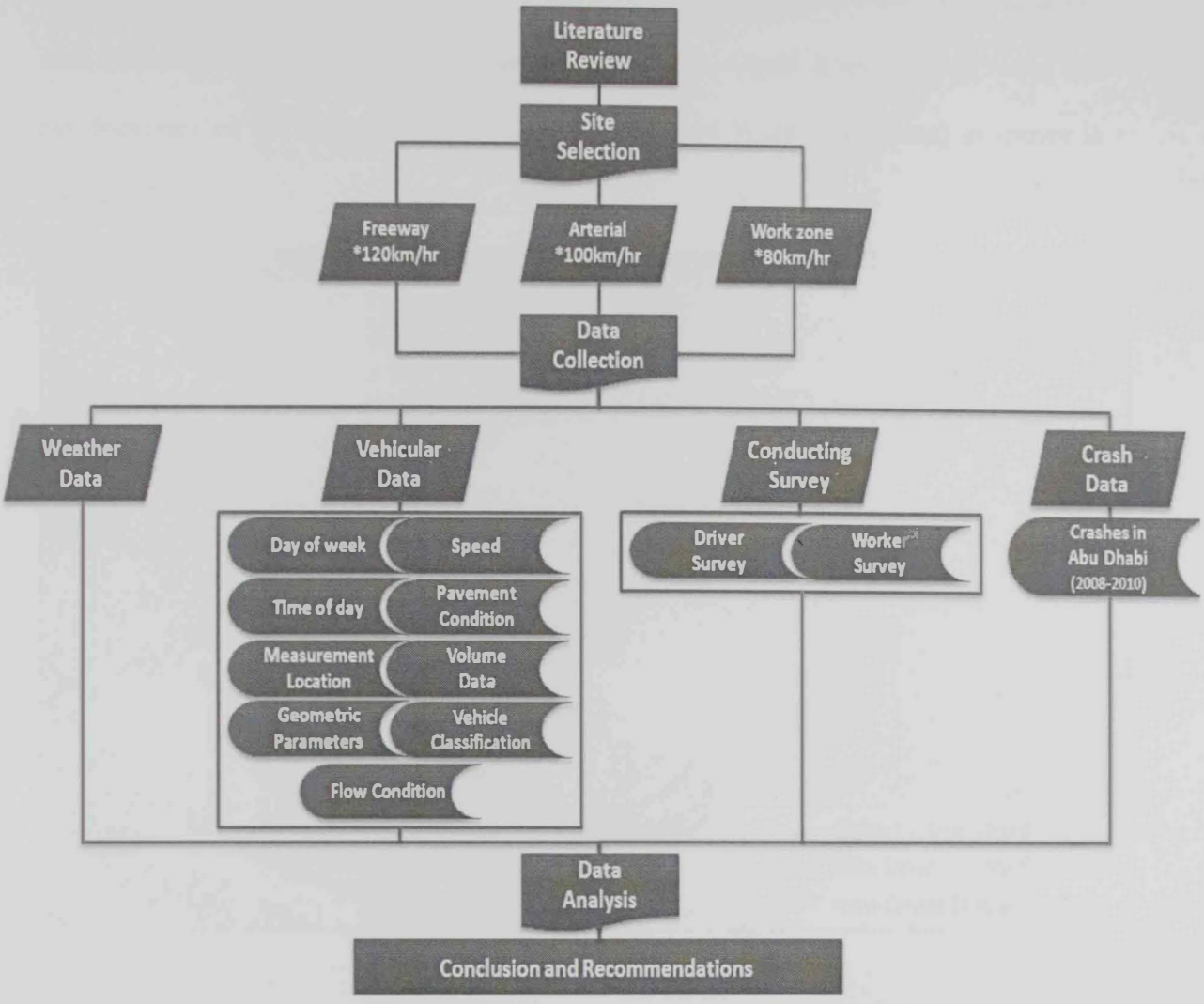
The study adopted a longitudinal approach and involved a three tier methodology:

i. Collecting before/after (or with/without PVMS) vehicular speed and classified volume metric, data at three different highway locations including one location close to a construction/maintenance site on a highway;

ii. Conducting driver / workers surveys, and

iii. Statistical analysis to evaluate the impact of PVMSs on road safety and road user satisfaction.

Figure 3.1 illustrates the detailed methodological steps adopted for the study. The specific methods involved in the site selection process, various vehicular data collection within the selected sites, and driver and worker surveys are discussed in detail in the following sections of this chapter.



*For analysis purposes the **allowable speed,** which is the posted speed limit with a margin of 20km/hr, will be considered as follows; Freeway 140km/hr, Arterial 120km/hr and Work Zone 100km/hr.

Figure 3.1: Flow Chart for Research Methodology

3.2 Site Selection

The criteria that were adopted for selecting the sites include the following:

i. Functional road hierarchy
ii. Daily traffic volumes
iii. Construction site or work-zone
iv. Roadway where speed enforcement is not in place such as speed cameras
v. Availability of historical crash data

On the basis of the above criteria, three different road segments within the Emirate of Abu Dhabi were selected with one location within Abu Dhabi Island (Urban Area) and two locations on the landside of Abu Dhabi (Rural and Work Zone areas) as shown in Figure 3.2.

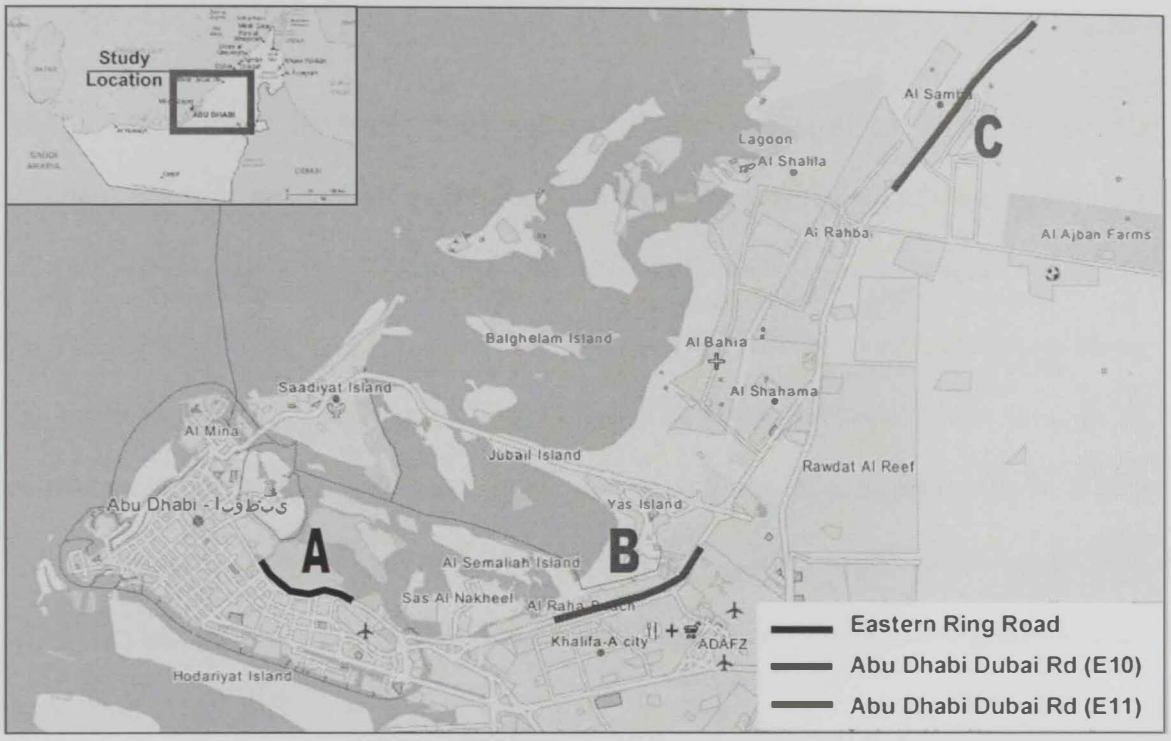


Figure 3.2: PVMS Site Locations

The details of the selected segments on these roads are as follows:

A. Abu Dhabi, Dubai Road (E11, Construction Zone)

This is a major freeway and a continuation of the E10 road connecting Abu Dhabi Emirate to the Dubai Road. The total length of the road segment is 11 km. It is a dual carriageway with four (4) lanes in each direction divided by a 20 – 50 meters wide median. There are residential areas along the south direction of the road. The northern direction is rural in nature passing various farms. At the time of the Study there was a

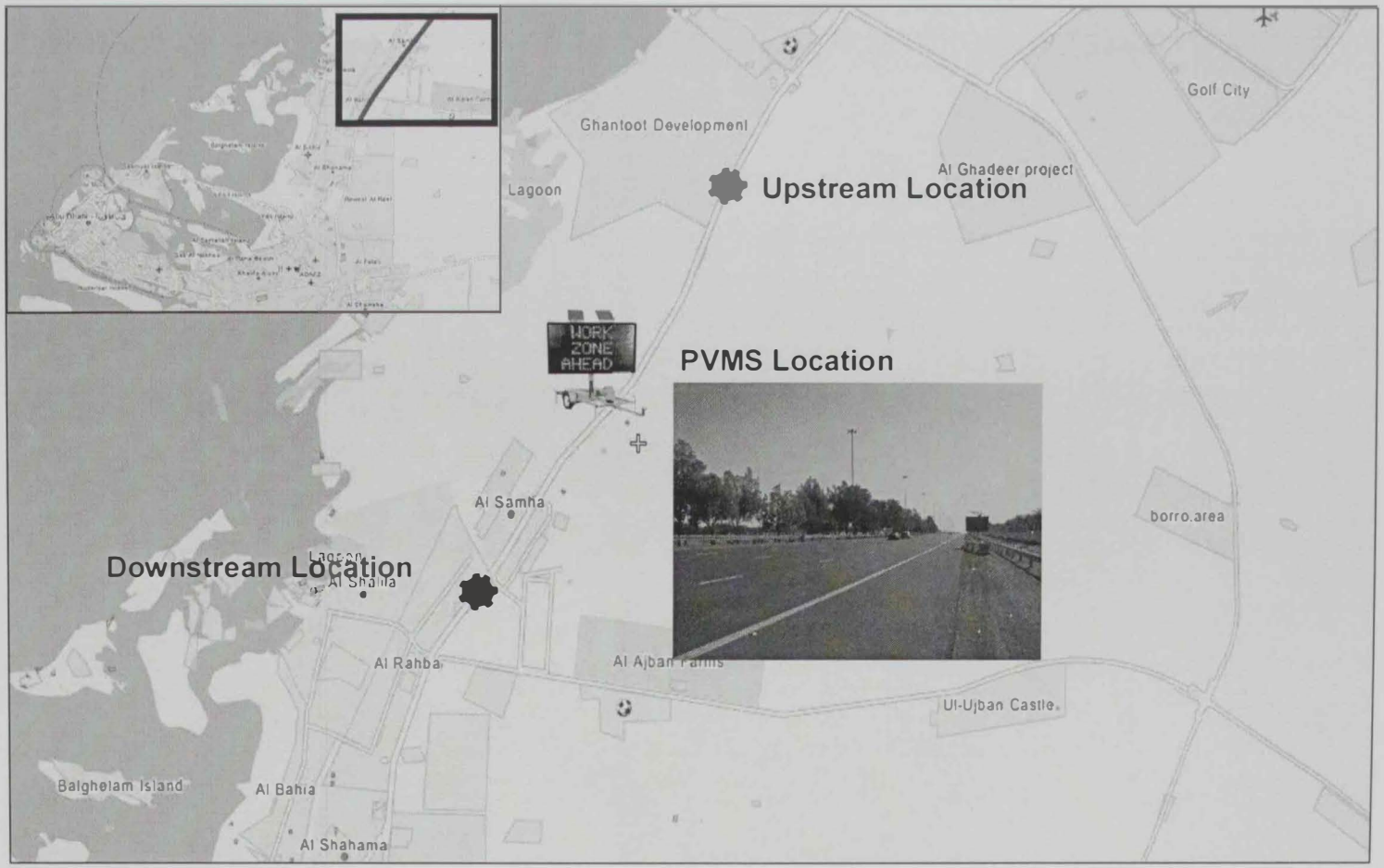
construction work zone within the selected study segment. The posted speed limit of this road segment along the construction zone was 80 km/hr (Allowable speed limit is 100 km/hr). Figure 3.3 illustrates the Abu Dhabi, Dubai Road (E11) study segment and the location of the PVMS.

B. Abu Dhabi, Dubai Road (E10)

This is also a major freeway connecting Abu Dhabi Emirate to the Dubai Emirate. It traverses the rural area in Khalifa Bin Zayed district. The total length of the road segment selected for this study is 4.30 km. It is a divided dual carriageway with four (4) lanes in each direction divided by 15 – 20 meters wide median. There are residential areas along the north direction of the road (Khalifa City). The south direction passes through an entrance/exit to Al Raha Mall and other new development such as the Raha Beach Developments. The speed limit of this road segment is 120 km/hr (Allowable speed limit is 140 km/hr). Figure 3.4 illustrates Abu Dhabi, Dubai Road (E10) study segment and the location of the PVMS.

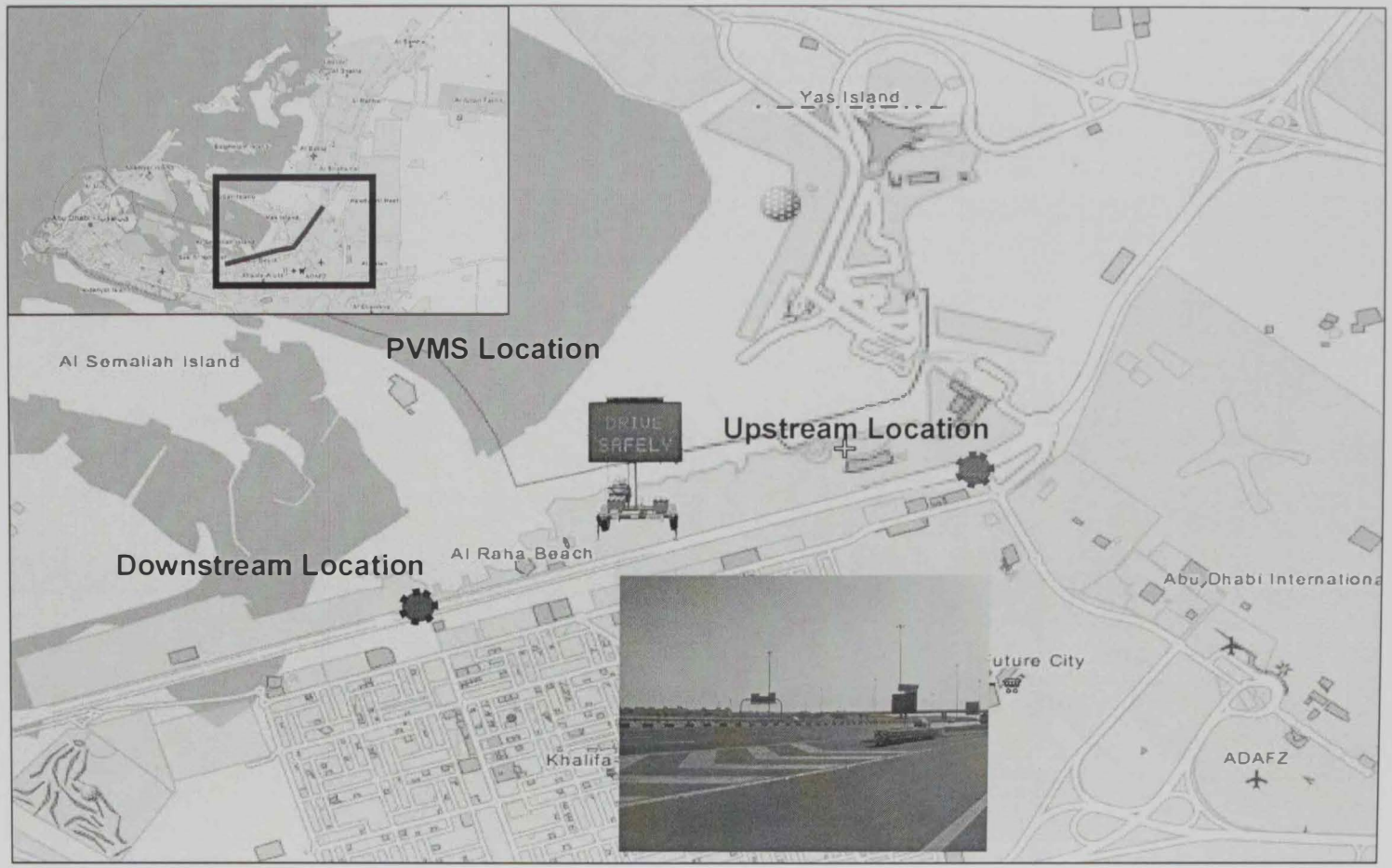
C. Eastern Ring Road

The Eastern Ring Road is a major road connecting Abu Dhabi Island and the main Island through Al Maqta & Khalifa Bridges. The total length of the study road segment is 3.30 km. It is a divided dual carriageway with four (4) lanes in each direction with a 3 – 6 meters wide median. There are residential areas along the east direction of the road. The west direction passes through Al Qurm Cornish. The speed limit of this road segment is 100 km/hr (Allowable speed limit is 120 km/hr). Figure 3.5 illustrates the Eastern Ring Road study segment and the location of the PVMS.



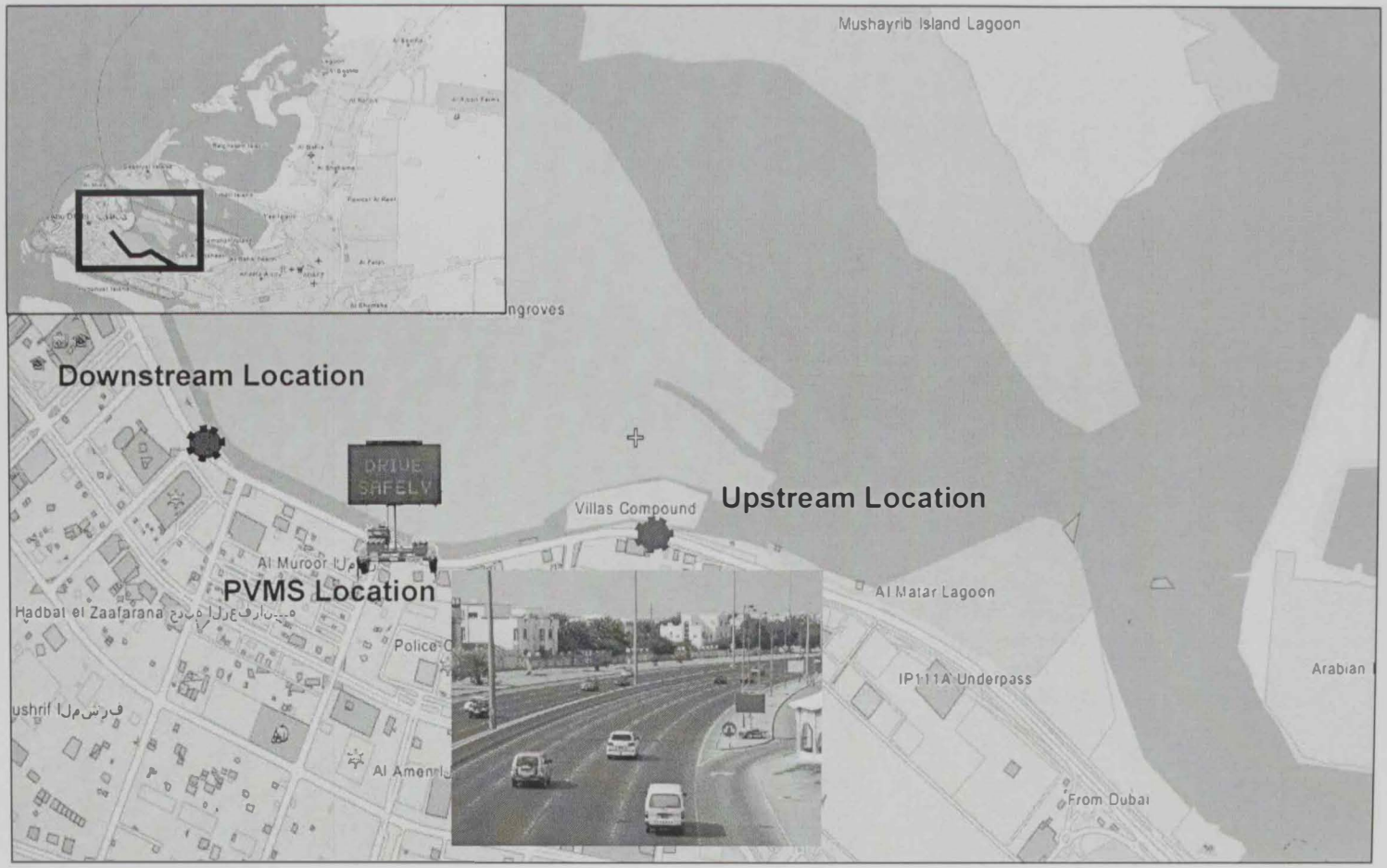
PVMS Location Coordinates: 276620m E 2734440m N

Figure 3.3: Abu Dhabi - Dubai Road (E11), Al Samha Area (Work Zone)



PVMS Location Coordinates: 255593m E 2705321m N

Figure 3.4: Abu Dhabi - Dubai Road (E10)



PVMS Location Coordinates: 238743m E 2705776m N

Figure 3.5: Eastern Ring Road

3.3 Vehicular Data Collection

Vehicular data were obtained from the pneumatic road tube deployed on the selected road segments. The vehicular data include:

- Individual vehicle speeds

  Speed is defined as the distance travelled per unit time. It is an indicator of the quality of journey and performance of the road network in accommodating traffic demand it is the rate at which vehicles travel (km/hr).

- Volume data

  Volume is defined as the number of vehicles passing a specific reference points on a road section within a specified period of time. In this study, the points are the proposed locations of the PVMS and the upstream and downstream points.

- Vehicle classification

  Vehicle Classification is defined as the types of vehicles passing through a specific reference point on a road section within a specified period of time. (Class1: Light Vehicle – LV, Class2: Medium Vehicle – MV, Class3: Heavy Vehicle - HV)

Other specific data were obtained through field observations. These included:

- Pavement conditions
- Geometric conditions (curve, horizontal curve, vertical curve)
- Time of day including (dawn, sunrise, noon, dusk, sunset, night) and
- Day of week (weekday, weekend, holiday, etc.)

The vehicular data collection stages, as shown in Figure 3.6, include;

Stage 1: Data Collection Period

Stage 2: Vehicular Data "Before Case"

Stage 3: Deploying PVMS

Stage 4: Vehicular Data "After Case"

Each stage is detailed as follows:

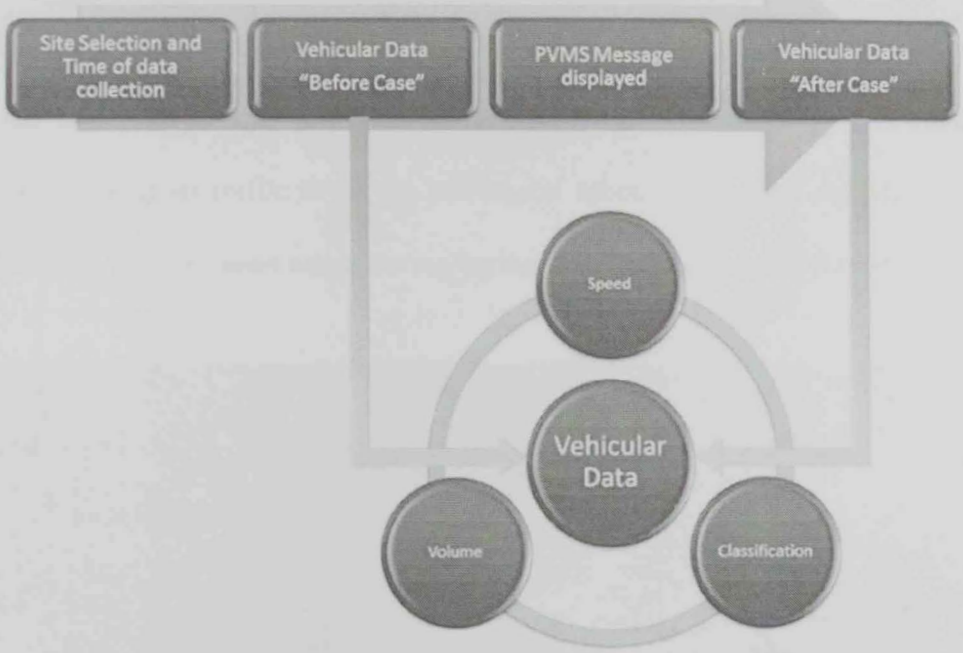


Figure 3.6: The Vehicular Data Collection Flow Chart

Stage 1: Data Collection Period

After obtaining all traffic survey permissions as shown in Appendix A, vehicular data was collected for 3 days during March 2011 by "i4 Research", a contracted survey company, and supervised by the researcher. The survey was conducted for 24 hours on Saturday, Sunday and Monday weekdays for both cases, "Before" and "After" PVMS implementation.

Stage 2: Vehicular Data "Before Case"

Speed surveys were carried before installing the PVMS on 18th March 2011 at the proposed PVMS locations as follows:

The setting up of the pneumatic road tube was started on Friday 18th March 2011 at 2:00am (Friday data was excluded since it's not collected for 24hrs), a team from i4 Research laid the pneumatic tubes at the proposed PVMS locations to allow traffic speeds to be monitored and recorded for a 24 hour study period. Police cars with crew (2 policemen) were available to ensure the road safety of the workers, as well as the drivers, during the blocking of traffic to fix the pneumatic tubes on the road asphalt. Figure 3.7 shows the snap photos views taken during laying the pneumatic tubes for "Before PVMS case".

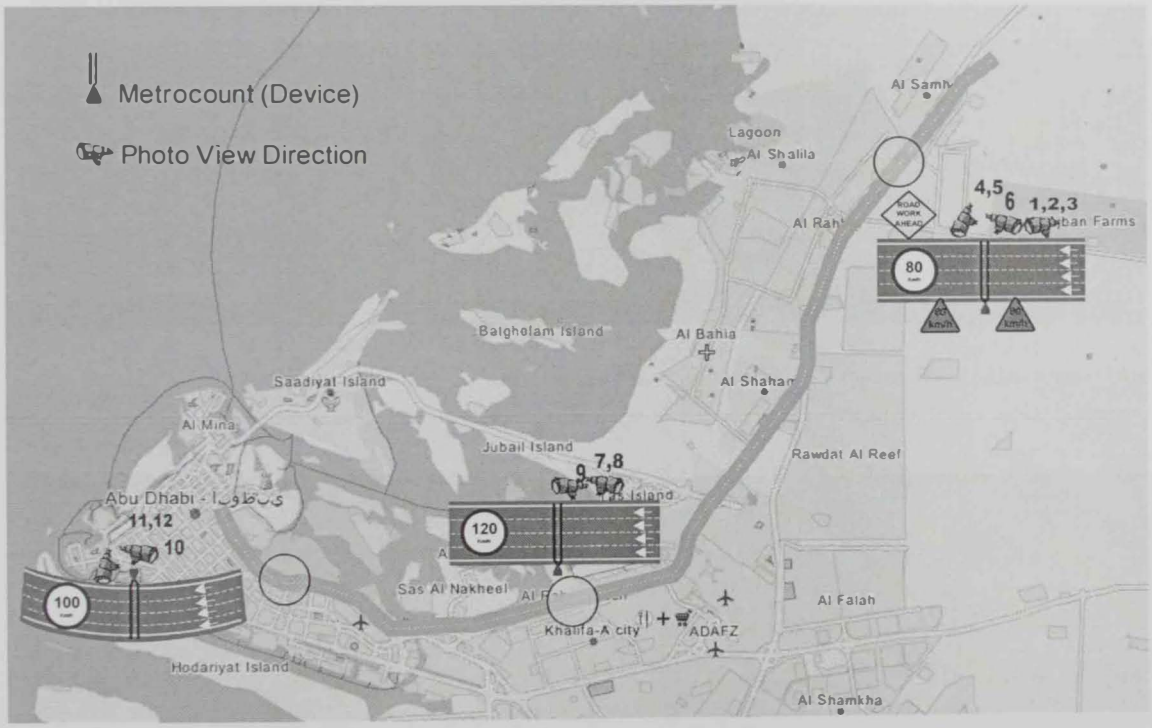


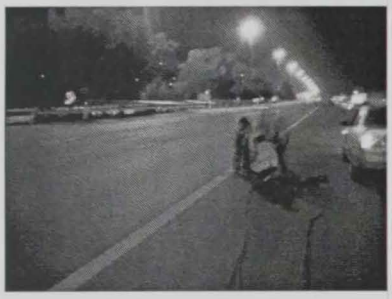
Figure 3.7: The Photos view for Before Case during setting up the pneumatic tubes

E11 – Samha Area (Construction Zone):

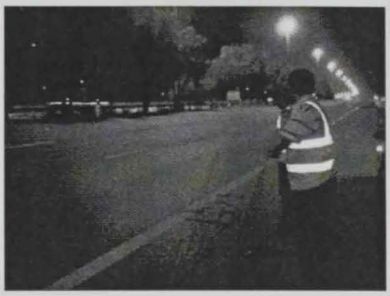
1. Gathering at Samha Area

2. Fully Equipped with Traffic Count tools

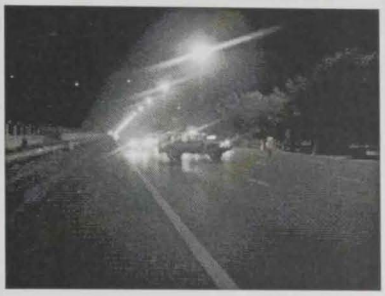
3. Setting up the pneumatic tubes at (Construction Zone)



4. Fixing Tubes



5. Ready for crossing the road



6. Police Car blocking the traffic

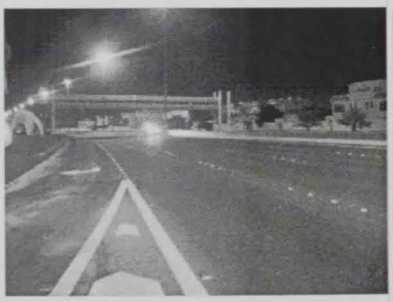
E10 – Raha Beach Area:

7. Police Car exist for safety issues

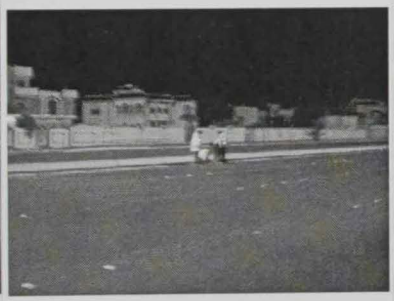
8. Setting up the Pneumatic Tube

9. Installing the Pneumatic Tube

Eastern Ring Road:



10. Police Car Blocking the traffic

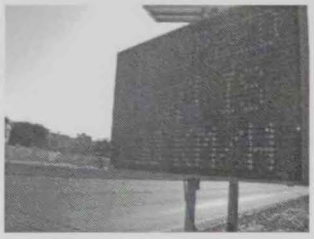


11. Installing the Pneumatic Tube

12. Installing the Pneumatic Tube

Stage 3: Deploying PVMS

The PVMSs were deployed to the proposed locations on Thursday 24th March 2011. The PVMS messages showed the posted speed limit, displayed in both Arabic and English languages as follows:

Eastern Ring Road	E10 – Raha beach	E11 – Construction Zone
		
MAX SPEED LIMIT IS 100 KM/H	MAX SPEED LIMIT IS 120 KM/H	MAX SPEED LIMIT IS 80 KM/H

Stage 4: Vehicular Data "After Case"

After deploying the PVMS, the speed survey was again conducted on Friday 25th March 2011 at the PVMS locations, upstream of the PVMS and downstream of the PVMS on the selected road segments (Friday data was excluded since it's not for 24hrs). Figure 3.8 shows the snap photos views taken during placing pneumatic tubes for "After PVMS case".

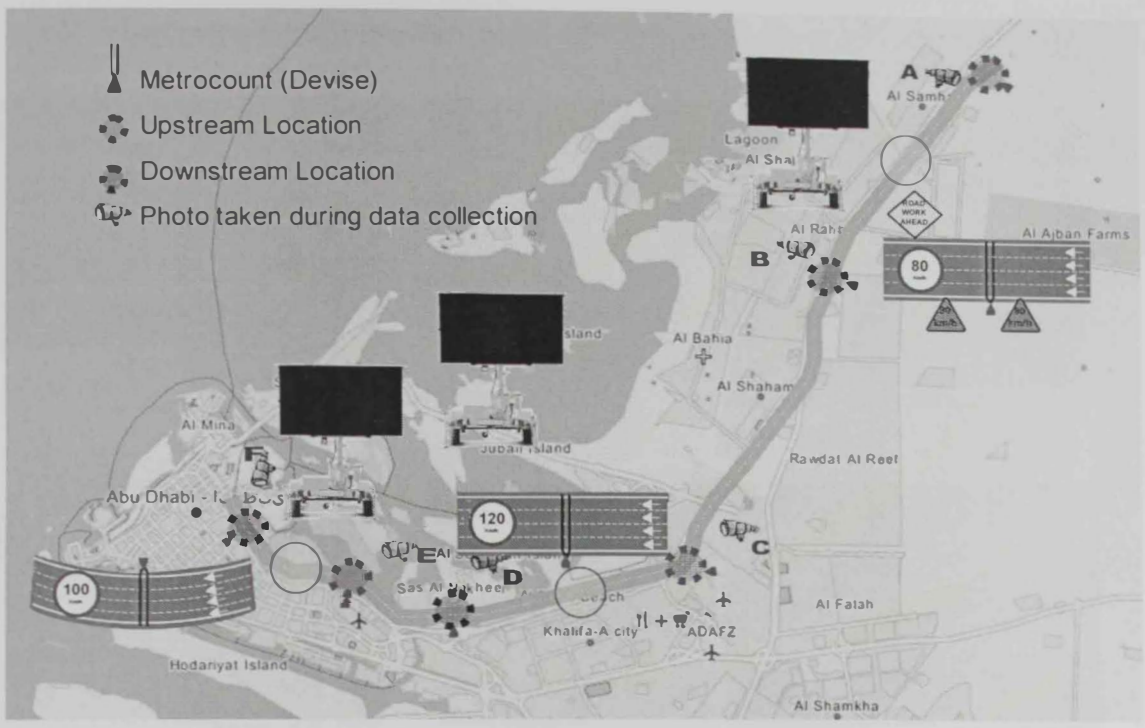
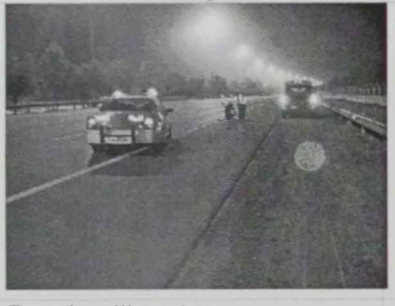
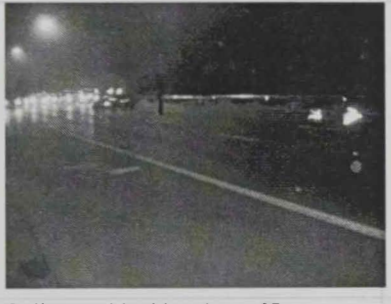


Figure 3.8: The Photos view for After Case during setting up the pneumatic tubes

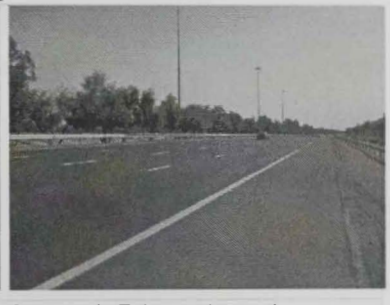
A. E11 – Upstream of Samha Area (Construction Zone):



Team installing tubes



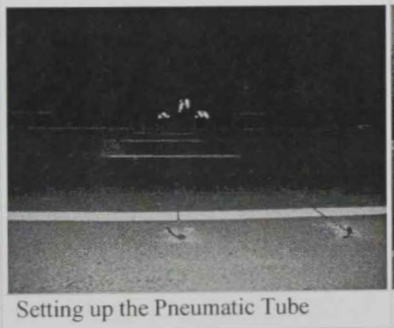
Police car blocking the traffic



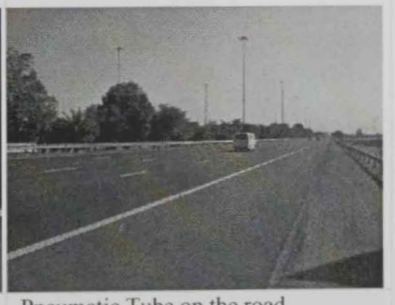
Pneumatic Tube on the road

B. E11 – Downstream of Samha Area (Construction Zone):

Team fixing the tubes on the road

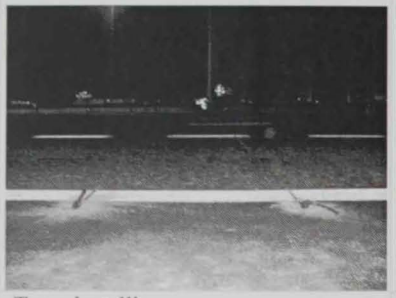


Setting up the Pneumatic Tube

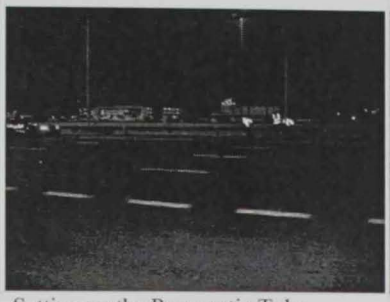


Pneumatic Tube on the road

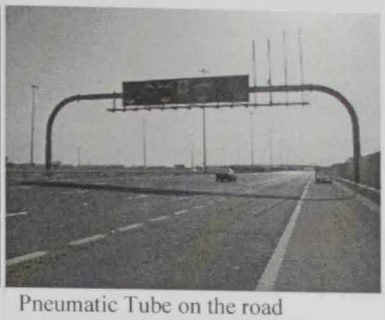
C. E10 – Upstream of Raha Beach Area:



Team installing



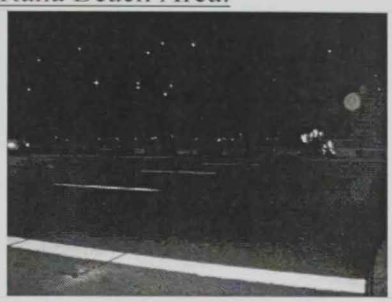
Setting up the Pneumatic Tube



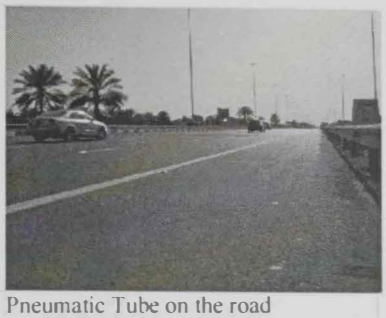
Pneumatic Tube on the road

D. E10 – Downstream of Raha Beach Area:

Team installing tubes at the downstream of Raha Beach Area



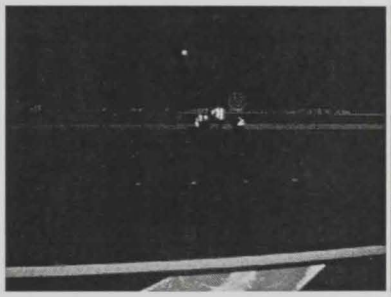
Setting up the Pneumatic Tube on the road



Pneumatic Tube on the road

E. E11 – Upstream of Eastern Ring Road:

Team installing tubes

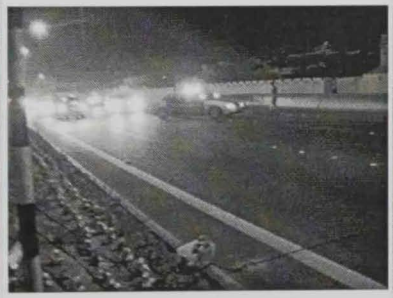


Setting up the Pneumatic Tube

Pneumatic Tube on the road

F. E11 – Downstream of Samha Area (Construction Zone):

Team installing tubes with Police support



Setting up the Pneumatic Tube on the road

Pneumatic Tube on the road

3.4 Driver/Worker Survey

The road user satisfaction evaluation focuses on the extent to which the PVMS is perceived to improve levels of satisfaction and compliance with the roadway system among the drivers of that roadway system. The customer satisfaction evaluation focuses on two key areas:

- Assess the ease with which drivers notice, understand, and use (or comply with) the countermeasures.
- Assess drivers' perceptions of safety in the overall context of the selected roadway segments.

In addition, a survey of construction workers was also conducted to assess the impact of the PVMSs on improving the safety at construction zone. The surveys administrated as part of this study were performed as an "intercept survey". The driver surveys were conducted at six different service locations namely: ADNOC Petrol Station, Al-Raha Mall, ABELA, Ministry of Interior, Traffic Department (Car Registrations) and Ministry of interior – Naturalization & Residency Administration. The surveys of workers were conducted at the Work Zone site (Al Samha Area) and different Roadwork zones within Abu Dhabi Emirate like the Arabian Gulf widening and Falcon Eyes Project. Figure 3.9 illustrates the survey locations and the questionnaire that was used for the satisfaction survey.

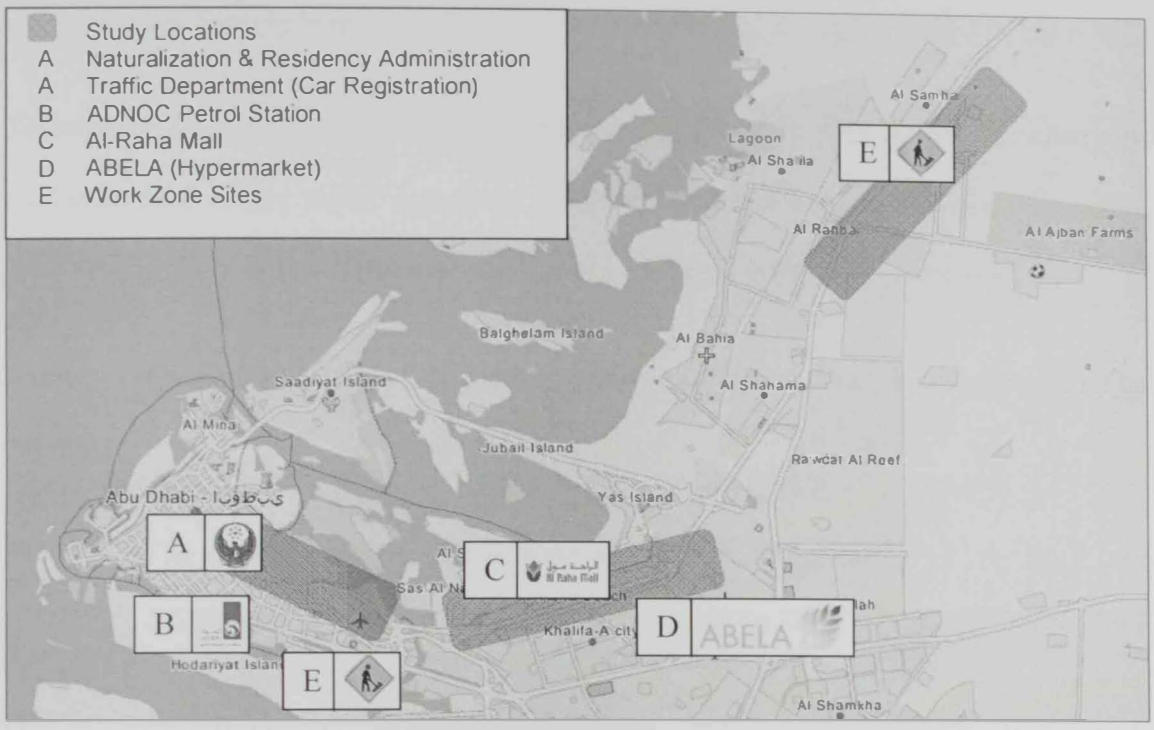


Figure 3.9: Survey Locations

The road user satisfaction survey was carried out using the questionnaire provided in Appendix B and Appendix C. The questionnaire was supplied translated in both Arabic and English.

3.4.1 Driver Surveys

The driver survey was conducted in the form of a face-to-face questionnaire survey in April 2011. The survey was conducted at multiple locations along the selected road segments. In total, 211 drivers were surveyed. The answers of the respondents to the questionnaire were recorded. After removing the records of respondents who did not complete the questionnaire, the final data set contained 200 surveys.

Driver Survey Sample Size

To estimate the required sample size for the required driver surveys for the quantitatively evaluation; the hourly traffic volume at the three locations was the base for the sample size. 10% of the hourly volume was used as the sample size of the driver surveys.

Table 3.1 represents the 10% of the average hourly traffic volume at the three locations as follows:

Table 3.1: The average hourly traffic volume for each location

Road/ Location	2011											
	March											
	Sat 19	Sun 20	Mon 21	Sat 26			Sun 27			Mon 28		
	T	T	T	U	T	D	U	T	D	U	T	D
Eastern Ring Road	215	244	245	205	214	212	237	246	246	234	242	243
E10 – Raha Beach	180	194	187	173	174	175	190	197	198	184	191	192
E11- Samha Area (Construction)	210	194	184	214	214	191	207	202	188	193	170	174

U: Upstream, T: Through, D: Downstream

As shown in Table 3.1, the average hourly traffic volume at the three locations for the before and after cases is 204. Accordingly, 204 driver surveys were conducted.

Of the 204 drivers who participated in the survey, 98% of the participants responded to the survey while 2% didn't fully respond to the survey.

Driver Survey Confident Level

As a reference, a sample size of 204 produces a margin of error of roughly 5.5% at the 90% confidence level. This means that the 90% confidence interval of a 50/50 split response to a yes/no question is ±5.5%.

Driver Questionnaire survey

The survey was conducted during April 2011. The driver questionnaire survey questions were developed to assess opinions on the benefits and challenges of assimilating PVMS, and suggestions for improving PVMS. In some of these questions, participants had the option to choose multiple answers. Other questions investigated drivers' opinions and preferences regarding various PVMS message display features. Some questions assessed subjects' awareness of messages in different message categories (danger warning, informative, and regulatory messages.). Other questions surveyed subjects' opinions regarding the usefulness of displayed messages. In other questions, participants had to rate the importance of their given answers. The driver survey consisted of 15 questions as follows:

- Gender, age and educational attainment for comparison purposes.
- Driving license validation to measure the experience of drivers.
- How often the driver travels on Abu Dhabi roads?
- Familiarity with the PVMS.
- How easily the driver was able to see and read the message?
- Reasons for any difficulty seeing and reading the messages on the PVMS.
- How often the driver reads the messages posted on the PVMS?

- What were the messages posted on the PVMS?
- How accurate was the information posted on the PVMS?
- What messages would be most important to be displayed to the driver on the PVMS?
- Agree / disagree on some statements regarding PVMS performance
- The usefulness of messages posted on the PVMS from the driver's point of view.
- Any comments on the subject of PVMS.
- Survey evaluation
- Any comments to improve the survey.

3.4.2 Worker Surveys

The main areas of evaluation for this work zone encompassed the following: safety, user perspectives, mobility, and productivity. In April 2011, many site visits were conducted to work zones adjacent to the selected road in order to assess the user perspective through conducting surveys among different levels of the workers on the site.

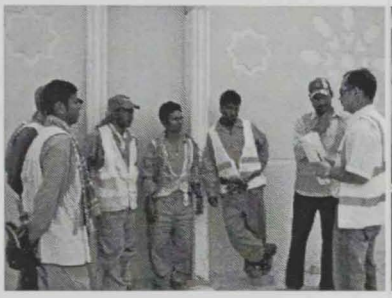
The selected work zone on E11 was located on the median of the road. There was no work on the road and no detour existed on the road during the data collection. Only fixed warning signs existed. The work zone had accesses onto the E11 road; heavy vehicles were allowed to access the site through these accesses. The default maximum speed limit for the E11 was 140 km/hr, so it was necessary to alert the drivers to a reduction in the maximum speed limit from140 km/hr to 80 km/hr in order to allow safe turns in/out the site. Fixed warning signs on the main road were used to reduce the speed limit so that vehicles and heavy trucks could enter and leave the site safely anytime using the fast lanes.

Worker Survey Sample Size

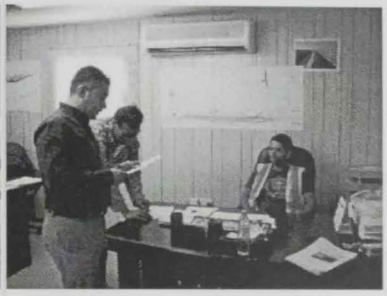
It was necessary to estimate the required sample size for the required worker surveys for the quantitatively evaluation, the number of staff available on the site was the base for the sample size. A sample of 10% of the total staff including workers and administration staff was selected as the sample size of the worker surveys.

There were about 500 employees at the work zone site. Accordingly 50 workers were interviewed in order to ensure that all questions were understood. In addition some of the foreign workers were interviewed with foreman assistance for translation purposes.

Explaining the work survey to the workers on site



Foreman translating to the workers



Interviewing Engineers

Worker Questionnaire survey

The questionnaire survey was aimed at evaluating whether the workers felt safer and whether they reacted positively when the PVMS was in operation through the work zone. The survey was conducted during April–May 2011 and was conducted face-to-face in order to ensure that all questions were responded to.

The worker survey consisted of 15 questions. In some of these questions, participants had the option to choose multiple answers. Other questions investigated worker's opinions

and preferences regarding various PVMS message display features. Some questions assessed subjects' perceived reaction to messages in different message categories (danger warning, informative, and regulatory messages.). Other questions surveyed subjects' opinions regarding the usefulness of displayed messages. In other questions, participants had to rate their assessment of the importance of the given answers. The survey covered the following:

- Gender, age and educational attainment for comparison purposes.
- Job of the worker on the site
- Driving license validation.
- How often workers travels through construction zones on Abu Dhabi roads?
- Familiarity with the PVMS.
- The best equipment used for traffic safety at the work zones.
- The usefulness of the PVMS
- What messages are thought would be most important to the worker to be displayed on the PVMS?
- Mentioned the messages posted on the PVMS you have seen.
- How often the worker reads the messages posted on the PVMS (If he can read)?
- How accurate is the information posted on the PVMS?
- Agree / disagree on some statements regarding PVMS performance
- Any comments on the PVMS subject.
- Survey evaluation
- Any comments to improve the survey.

3.5 Weather Information

Road weather information was collected from the National Center of Metrology and Seismology in Abu Dhabi. There are two stations located in Abu Dhabi Island at Marina Mall and Abu Dhabi Land at Abu Dhabi Airport as shown in Figure 3.10. Both stations were utilized in this study to provide the weather conditions during the survey period along the selected road segments.

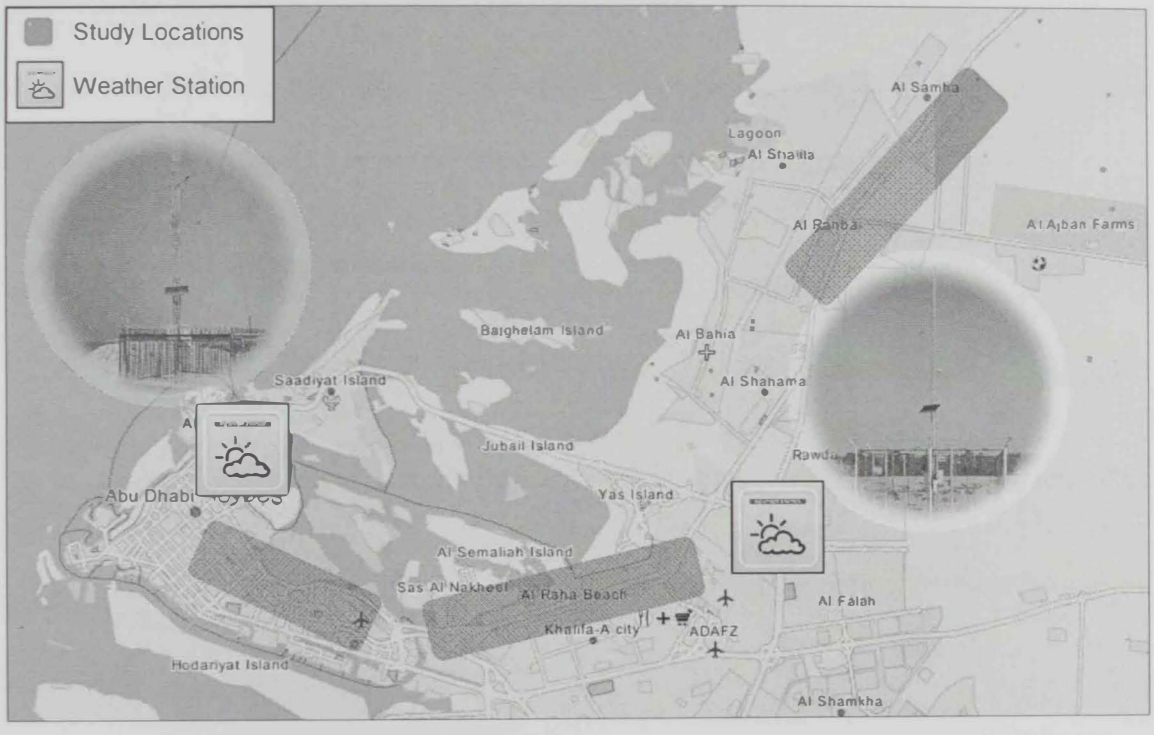


Figure 3.10: Weather Stations Location

The weather data included Wind Speed (m/s), Temperature (°C) and Relative Humidity (%). A sample of the weather information is attached in Appendix D.

3.6 Crash Data

Road accident data was obtained from the Ministry of Interior - Abu Dhabi Police Crash Database from 2008 to 2010. The crash data was categorized according to fatality, degree of injury - serious, moderate and slight. Accidents records were collected during the study duration for the selected study locations. Details of the crash data is attached in Appendix E.

3.7 Data Analysis Methodology

In order to evaluate the effectiveness of PVMS, two methods of data analysis were adopted. These included descriptive statistics and analytical statistics.

The overall objective of the statistical analysis was to:

- Examine the significance and differences of speed means for before and after installing PVMS cases.
- Determine the crash data trends on the selected study sections for before and after deployment of PVMS.
- Assess the driver's and worker's feedback on their opinion regarding the use of PVMS.

3.7.1 Speed Data Analysis

A statistical analysis was performed in order to quantify the differences in the measures of effectiveness (MOEs), which are attributable to the installation of the PVMS. The statistical analysis is based on a 'before and after' study of the speed data collected on the selected three road segments for three days. In the 'before and after' study plan (Figure 3.11) speed data (MOE) were compared 'before' and 'after' the installation of the PVMS.

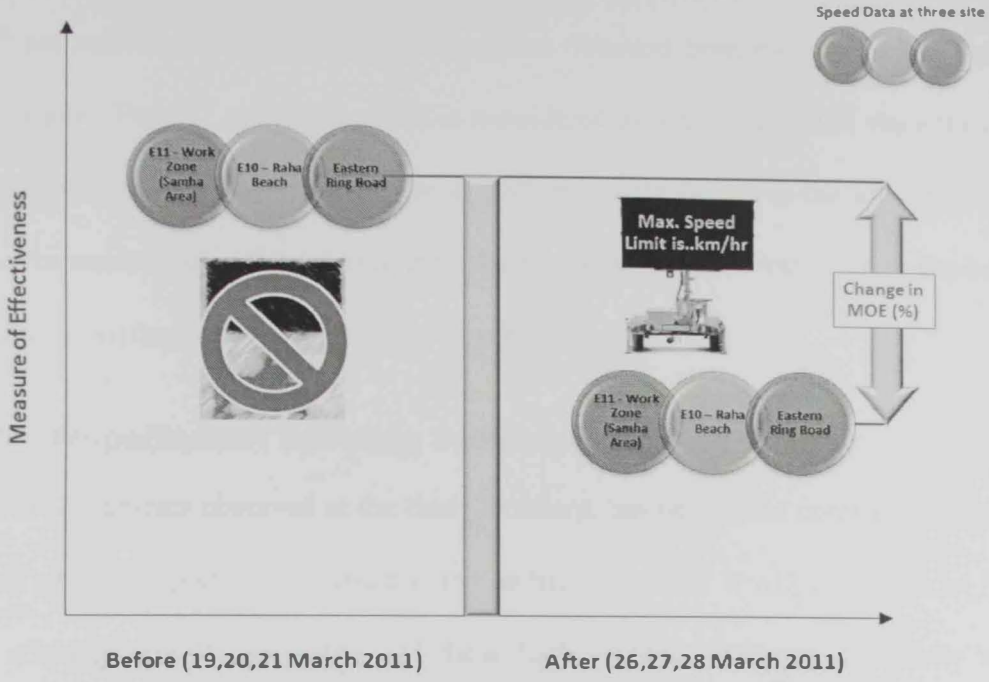


Figure 3.11: Before and After Evaluation Plan

Variations in speed were studied by analyzing the collected data using statistical techniques for different cases. In order to isolate the impact of PVMS on vehicle speeds, the effect of traffic volumes, as well as weather, day of week (i.e. weekend and working days) and time-of-day (i.e. night and day) were considered. The following MOEs are considered in the analysis for the evaluation purposes:

3.7.1.1 Average speed

The average speed for both cases before and after is compared to give the percentage of reduction. Also, the average speed for the upstream and downstream is compared with the average speed at the PVMS location for the before case when the speed limit at these locations is identical.

3.7.1.2 85th percentile speed

The 85th percentile speeds is calculated using data obtained from the speed survey at the three locations. The 85th percentile speed is considered as one of the MOE since it can be compared for both cases before and after. If 85th percentile speeds in the after period are closer to the mean, traffic flow during the after period is smoother than during the before period, thus contributing to a reduction in observed speeds.

3.7.1.3 Proportions of Speeding Vehicles

The speeding vehicles observed at the three locations can be used to compare the impact of PVMS on the proportion of vehicle going on higher speeds. It will be beneficial if the PVMS could reduce the proportion of these higher speeds vehicles, especially when drivers are approaching the work zones. The percentages of speeding vehicles can also be used as a rough measure of speed limit compliance based on the following classifications:

- 10 km/h over speed limit.
- 20 km/h over speed limit.
- 30 km/h over speed limit.
- 40 km/h over speed limit.

3.7.1.4 Speed Statistical Test

A two-sample t-test will be used to determine any significant difference between the mean value of the speed of before (μ_b) and after (μ_a) the PVMS was deployed, under the assumption that the sampled populations are normally distributed. The null and alternative hypotheses are as follows:

> *H_o: There is no difference in the mean speed, before (μ_b) and after (μ_a) the implementation of the PVMS.*
>
> *H_a: There is a statistically significant difference in speed data between the before(μ_b) and after (μ_a) the implementation of the PVMS.*

One sample test was also carried out to compare the collected speed data with the road speed limit (hypothesis mean). The hypotheses developed for the t-test as follows:

> *H_o: There is no difference in the mean speed comparing the before (μ_{bp}) and after(μ_{ap}) the implementation of the PVMS cases with the road speed limit.*
>
> *H_a: There is a statistically significant difference in mean speed comparing the before (μ_{bp}) and after (μ_{ap}) the implementation of the PVMS cases with the road speed limit.*

A two sample t-test was carried for the speed mean before deploying the PVMS (μ_b) with the upstream (μ_u) and downstream (μ_d) speed mean after deploying the PVMS. Each case was considered separately to measure the effectiveness of PVMS on driver behaviors. The null and alternative hypotheses are as follows:

> *H_o: There is no difference in the mean speed, before (μ_b) and after – Upstream(μ_u) /Downstream(μ_d) the implementation of the PVMS.*
>
> *H_a: There is a statistically significant difference in speed mean between the before(μ_b) and after – Upstream(μ_u) /Downstream(μ_d) the implementation of the PVMS.*

3.7.2 Crash Data Analysis Methodology

Crash evaluation after the PVMS installation will require several years of crash data in order to obtain a statistically significant sample. In this study, the PVMSs were installed for a short time during speed survey. Therefore, the crash trend analysis can't measure the impact of PVMS. However, it is important to realize that there are many influences on vehicle crashes making it difficult to determine with absolute certainty the causes and effects of crashes.

3.7.3 Satisfaction Survey Data Analysis Methodology

This is mainly qualitative and descriptive in nature. Drivers and workers perceptions were analysed based on ranking and Likeat scale with regard to their opinion on a number of subjects that were presented in the questionnaire.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents the analysis of data collected during the survey period for the three case study road sections. In order to evaluate the effectiveness of PVMS, a cross-sectional statistical analysis methodology has been employed in addition to the road user opinion on the satisfaction level with the PVMS. Cross sectional analysis methodology is based on an evaluation of the performance of the subject MOE for the 'before and after' study for the selected three locations. The evaluation involves an application of descriptive and analytical statistical methods. The following sections provide the results of data analysis.

4.2 Speed Descriptive Statistics

The data at each site, for each day, is summarized and categorized into: volume, mean speed, maximum speed, minimum speed, weather condition, % class 1 vehicles, % class 2 vehicles and % class 3 vehicles and mean speed for each class and were recorded for each day for the before or after deployment of the PVMS. Tables 4.1 to 4.3 show the descriptive statistical for speed data collected from all site.

The speed surveys data at E11 road (Work zone) on day 2 from 0730 to 0830 for after case was excluded due to minor two car accidents nearby the PVMS location. The accident reports, attached in Appendix A, were collected from SAEED, a company associated with the police which manages car accidents in Abu Dhabi. The accident reports are not representing the exact location and the timing of the accident.

Table 4.1: Speeds on E11 at Al Samha Section (Work Zone) for 24hrs each day

	Before			After			Upstream			Downstream		
Date	190312	200312	210312	260312	270312	280312	260312	270312	280312	260312	270312	280312
Weather	Clear 22.4°C	Clear 21.2°C	Clear 20.7°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C
N	50452	42287	36905	51255	45099	38034	51423	45276	38431	46017	40754	34851
Mean (km/hr)	124.6	124.0	123.7	124.9	124.8	123.4	122.1	121.9	121.1	125.9	125.6	124.8
Median (km/hr)	126.5	126.1	126	126.8	127.1	125.7	122.9	122.9	122.2	127.5	127.2	126.7
Maximum (km/hr)	196.5	195	190.7	199.4	196.2	192.2	198.6	198.1	198.3	199.7	198	197.4
St. dev	17.7	18.2	18.5	17.25	17.74	18.08	18.80	19.06	19.55	17.91	18.49	19.16
Class1%	87%	85%	84%	84%	84%	84%	89%	89%	87%	88%	88%	87%
Class2%	11%	12%	12%	13%	13%	13%	8%	8%	9%	9%	9%	10%
Class3%	3%	3%	4%	3%	3%	3%	3%	3%	4%	2%	3%	3%
Mean Class1	127.2	127.1	127.3	127.8	128.0	126.8	125	124.9	124.4	128.7	128.6	128.2
Mean Class2	104.9	102.6	100.1	107.6	105.6	103.6	94.6	92.98	92.23	101.9	99.6	97.9.
Mean Class3	118.9	118.3	120.4	119.5	120.6	119.7	115.1	114.8	115.8	116.9	118.3	117.8

* From 0800 to 2000 there was a dust haze
- On 27th March – After case: From 0730 to 0830 Speed data were excluded due to accident at PVMS location
- On 28th March – After case: From 1900 to 2359 Speed Data were excluded due to error in counter instrument at PVMS location

Table 4.2: Speeds on E10 at Al Raha Beach section for 24hrs each day

	Before			After			Upstream			Downstream		
Date	190312	200312	210312	260312	270312	280312	260312	270312	280312	260312	270312	280312
Weather	Clear 22.4°C	Clear 21.2°C	Clear 20.7°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C	*Clear 26.0°C	Clear 22.7°C	Clear 22.5°C
N	43103	46636	44870	41767	47235	45859	41526	45787	44157	41932	47592	46145
Mean (km/hr)	126.0	126.7	126.6	125.0	125.7	125.6	114.9	115.8	115.7	110.5	111.8	111.3
Median (km/hr)	129.7	130.2	129.7	128.7	129.2	128.9	115.5	116.3	116.0	111.7	112.9	112.2
Maximum (km/hr)	199.6	199.8	199.7	199.9	199.0	198.4	199.5	196.4	199.3	195.4	197.9	199.9
St. dev	22.76	22.58	22.49	22.65	22.49	22.55	20.59	20.75	20.91	20.37	20.46	20.45
Class1%	73%	74%	73%	71%	73%	73%	85%	86%	86%	86%	88%	87%
Class2%	23%	21%	22%	24%	22%	22%	10%	9%	9%	9%	8%	8%
Class3%	4%	5%	5%	4%	5%	5%	4%	4%	4%	4%	4%	4%
Mean Class1	129.4	129.9	130	129.1	129	129	118.4	118.9	118.9	114.2	114.9	114.4
Mean Class2	118.7	119.3	119.1	117.9	118.4	118.1	95.6	95.5	95.5	86.9	87.88	87.1
Mean Class3	102.9	107.6	106.7	99.2	106.8	107.3	91.1	96.6	95.3	87.6	94.2	93.5

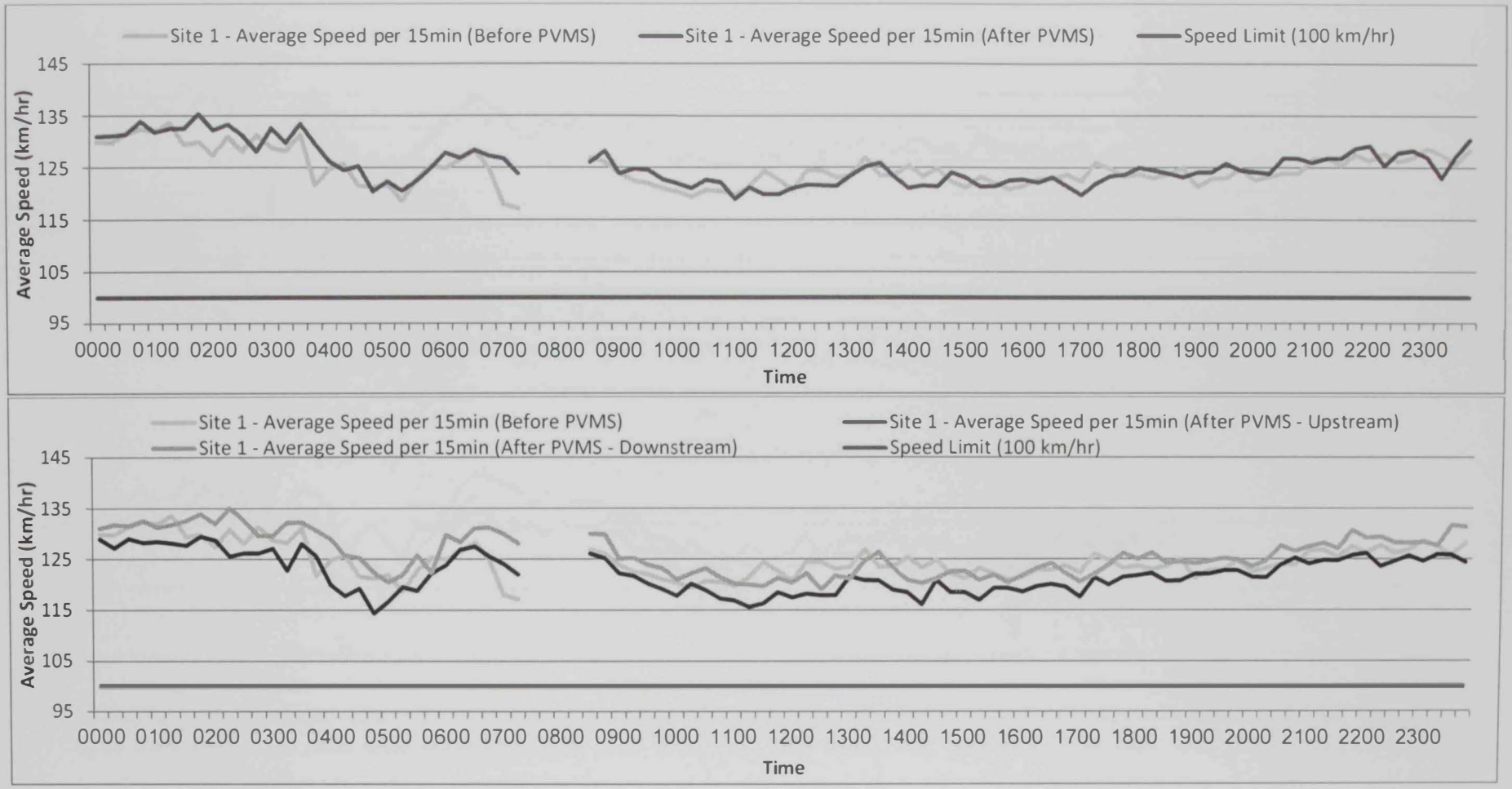
* From 0800 to 2000 there was a dust haze

Table 4.3: Speeds on Eastern Ring Road section for 24hrs each day

	Before			After			Upstream			Downstream		
Date	190312	200312	210312	260312	270312	280312	260312	270312	280312	260312	270312	280312
Weather	Clear 22.1°C	Clear 22.3°C	Clear 20.9°C	Clear 26.2°C	Clear 22.4°C	Clear 22.5°C	Clear 26.2°C	Clear 22.4°C	Clear 22.5°C	Clear 26.2°C	Clear 22.4°C	Clear 22.5°C
N	51644	58470	58695	51397	59117	58173	49260	56947	56194	50974	58954	58412
Mean (km/hr)	94.1	93.2	92.9	93.4	91.6	91.5	97.0	96.5	96.0	91.5	90.0	89.8
Median (km/hr)	95	94	93.5	94	92.2	92.2	96.8	96.4	95.9	91.2	89.7	89.3
Maximum (km/hr)	190.8	167.8	195.6	179.2	167.1	173.7	192.1	180.3	180.1	169.9	179.6	168.9
St. dev	14.60	14.58	13.85	13.93	13.69	13.65	14.97	14.38	14.34	13.50	13.32	13.26
Class1%	86%	86%	85%	86%	86%	86%	87%	87%	87%	86%	86%	86%
Class2%	9%	7%	7%	9%	7%	7%	8%	7%	7%	8%	7%	7%
Class3%	5%	8%	8%	5%	7%	8%	5%	6%	6%	5%	7%	7%
Mean Class1	95.5	94.2	94	94.9	92.8	92.7	98.8	98	97.5	93.1	91.3	91
Mean Class2	82.6	82.9	82.3	81.5	81	80.8	82.4	82.6	82.2	79	78.3	78
Mean Class3	88.5	89.7	89.3	87.2	87.6	87.8	88.2	91.1	90.1	84.5	84.7	84.5

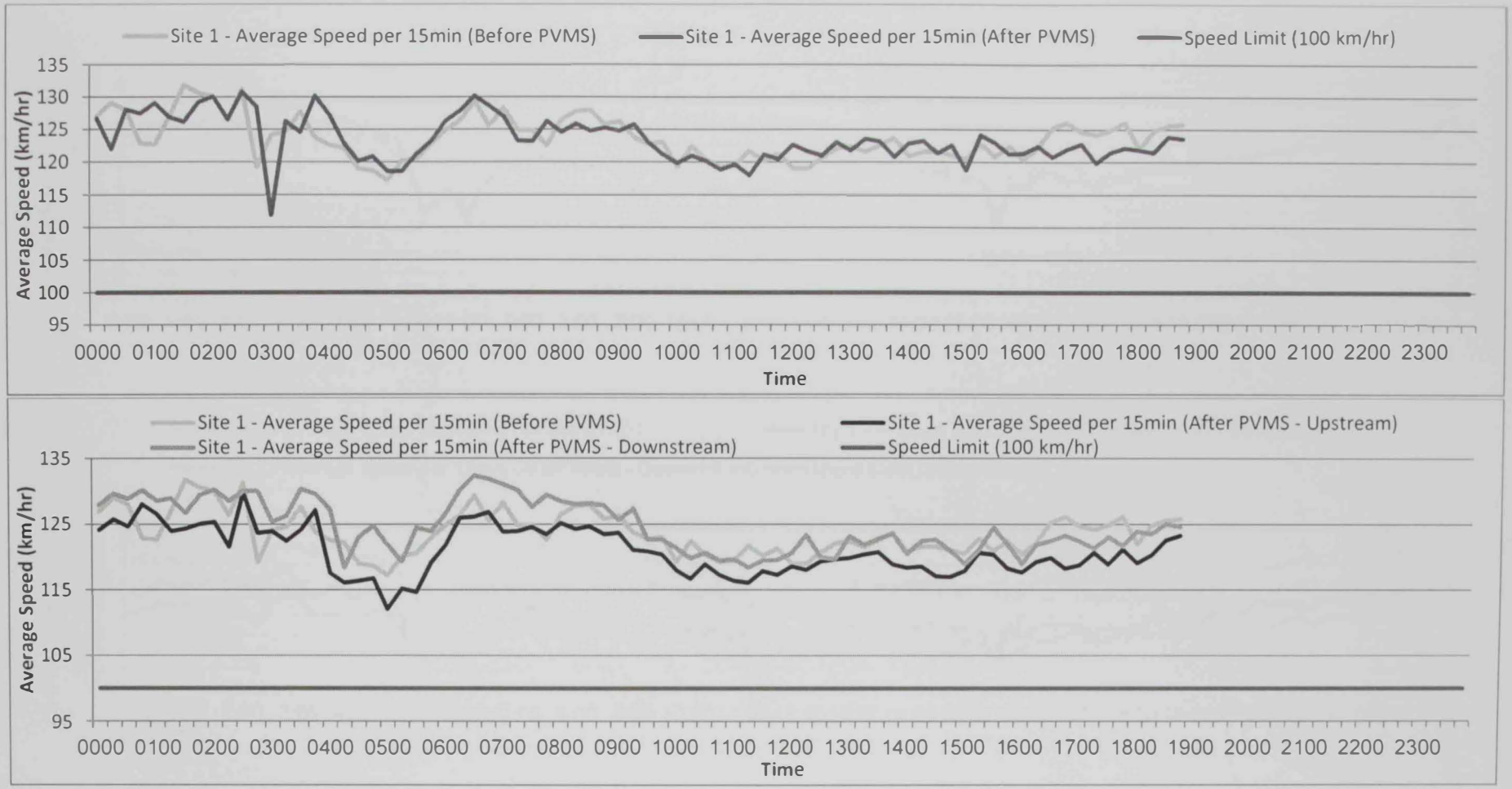
The average speed profiles for both the "before" and "after" cases for the study road sections at 15 minutes intervals are illustrated in Figure 4.1, 4.2 and 4.3 respectively. In addition, the speed data histogram graphs for both cases in each day are presented in a normal distribution chart where normal distribution is required to carry t-test. Figures 4.4, 4.5 and 4.6 show the speed distribution for E11, E10 and Eastern Ring Road sections respectively.

Figure 4.1: Average Speed Profile – E11 (Work Zone), Day 1



*Corrupted Speed Data is excluded: 0730 to 0830 due to an accident at PVMS location

Figure 4.2: Average Speed Profile – E11 (Work Zone), Day 2



*Corrupted Speed Data is excluded: 1900 to 2400 due to error in counters at PVMS location

Figure 4.3: Average Speed Profile – E11 (Work Zone), Day 3

Figure 4.4: Average Speed Profile – E10 (Al Raha Beach), Day 1

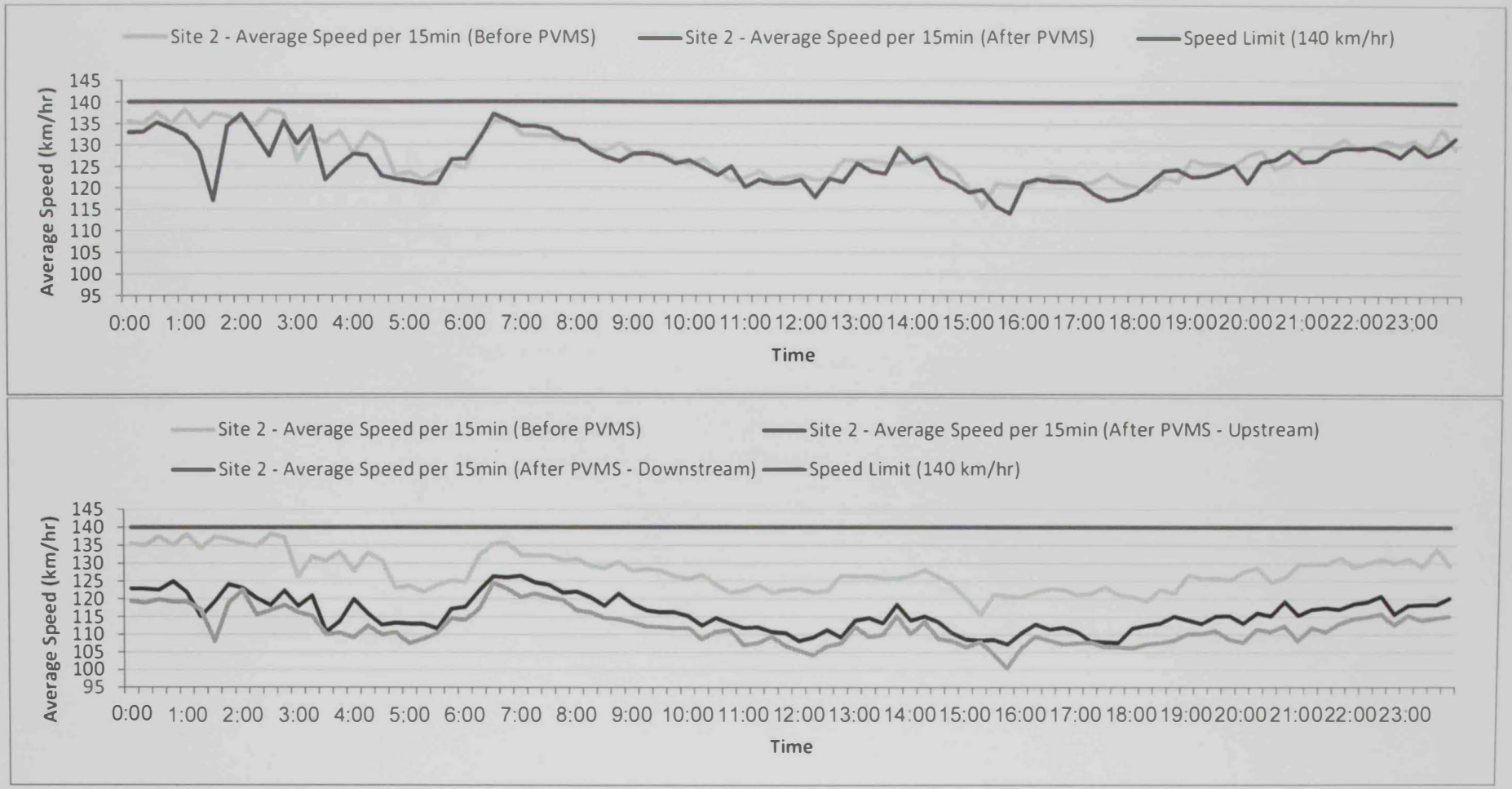


Figure 4.5: Average Speed Profile – E10 (Al Raha Beach), Day 2

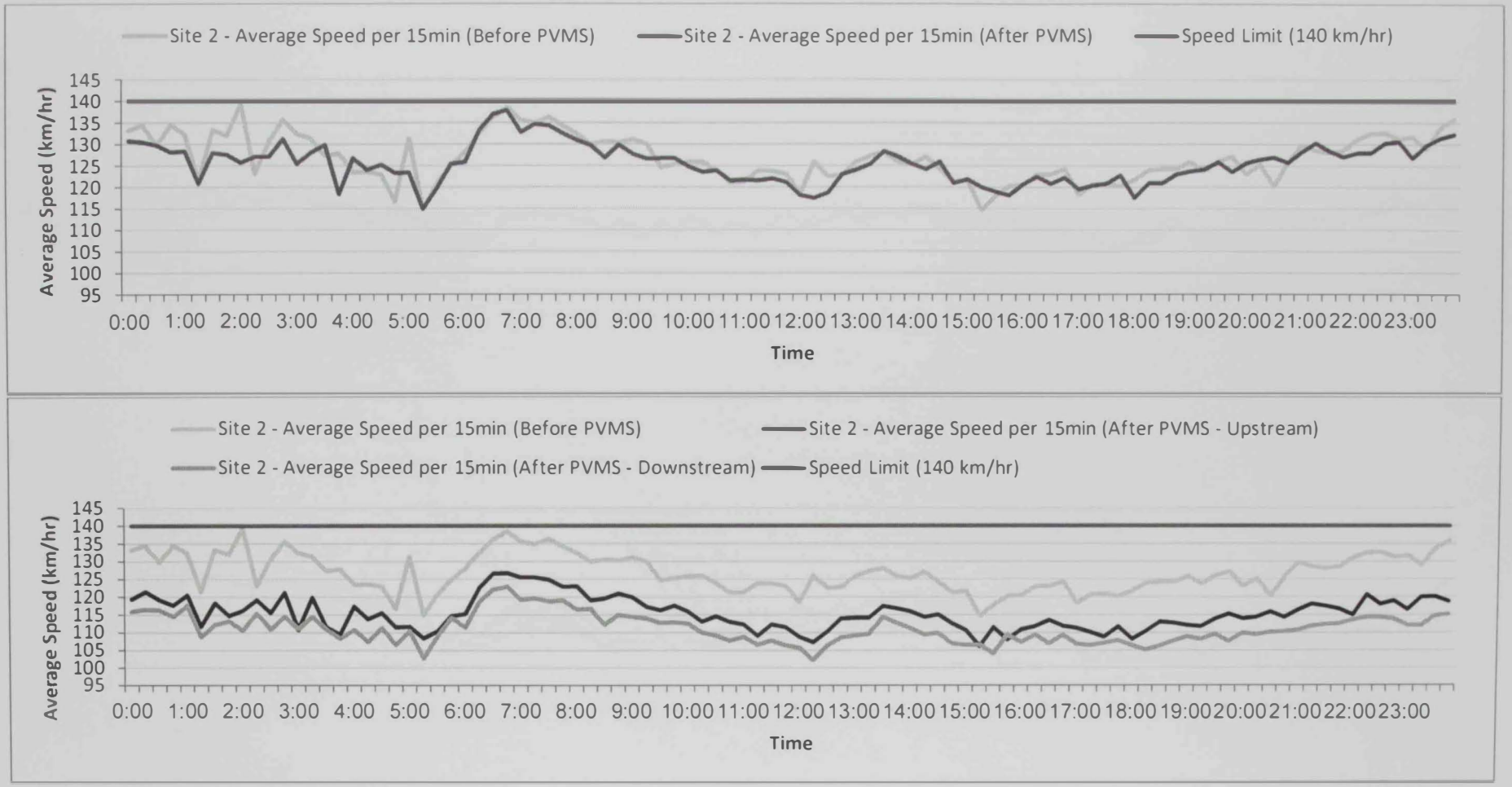


Figure 4.6: Average Speed Profile – E10 (Al Raha Beach), Day 3

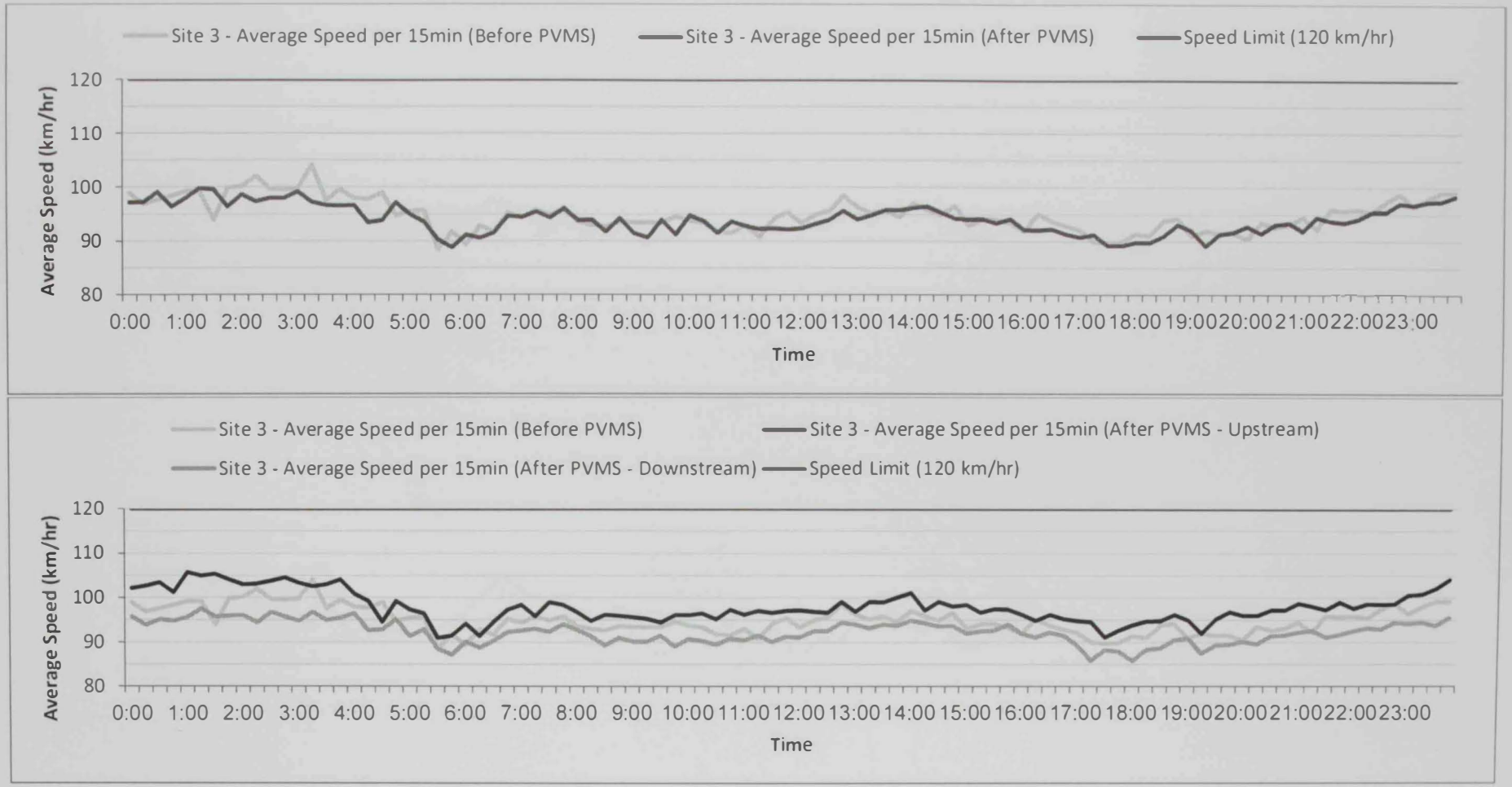


Figure 4.7: Average Speed Profile – Eastern Ring Road, Day 1

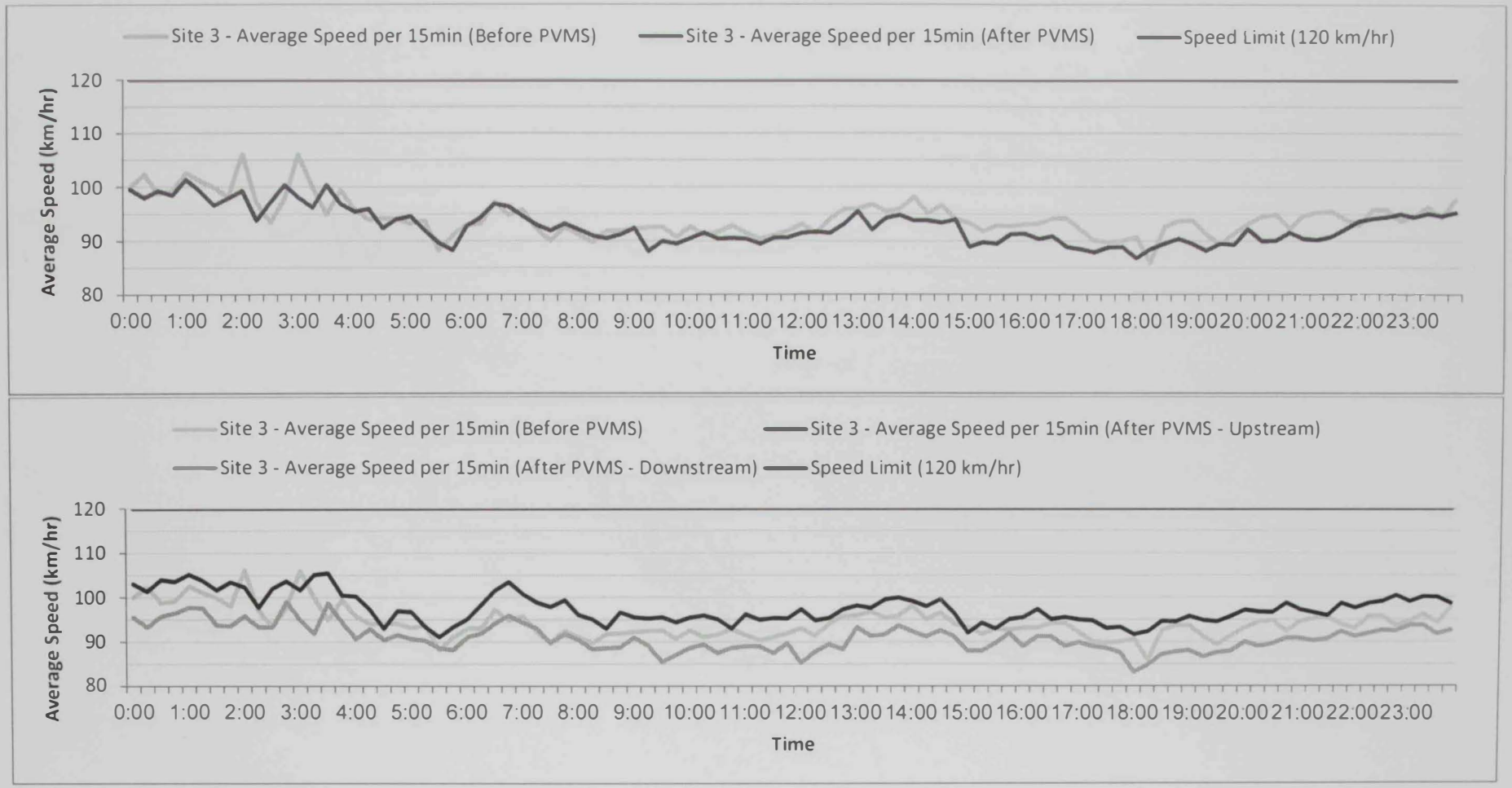


Figure 4.8: Average Speed Profile – Eastern Ring Road, Day 2

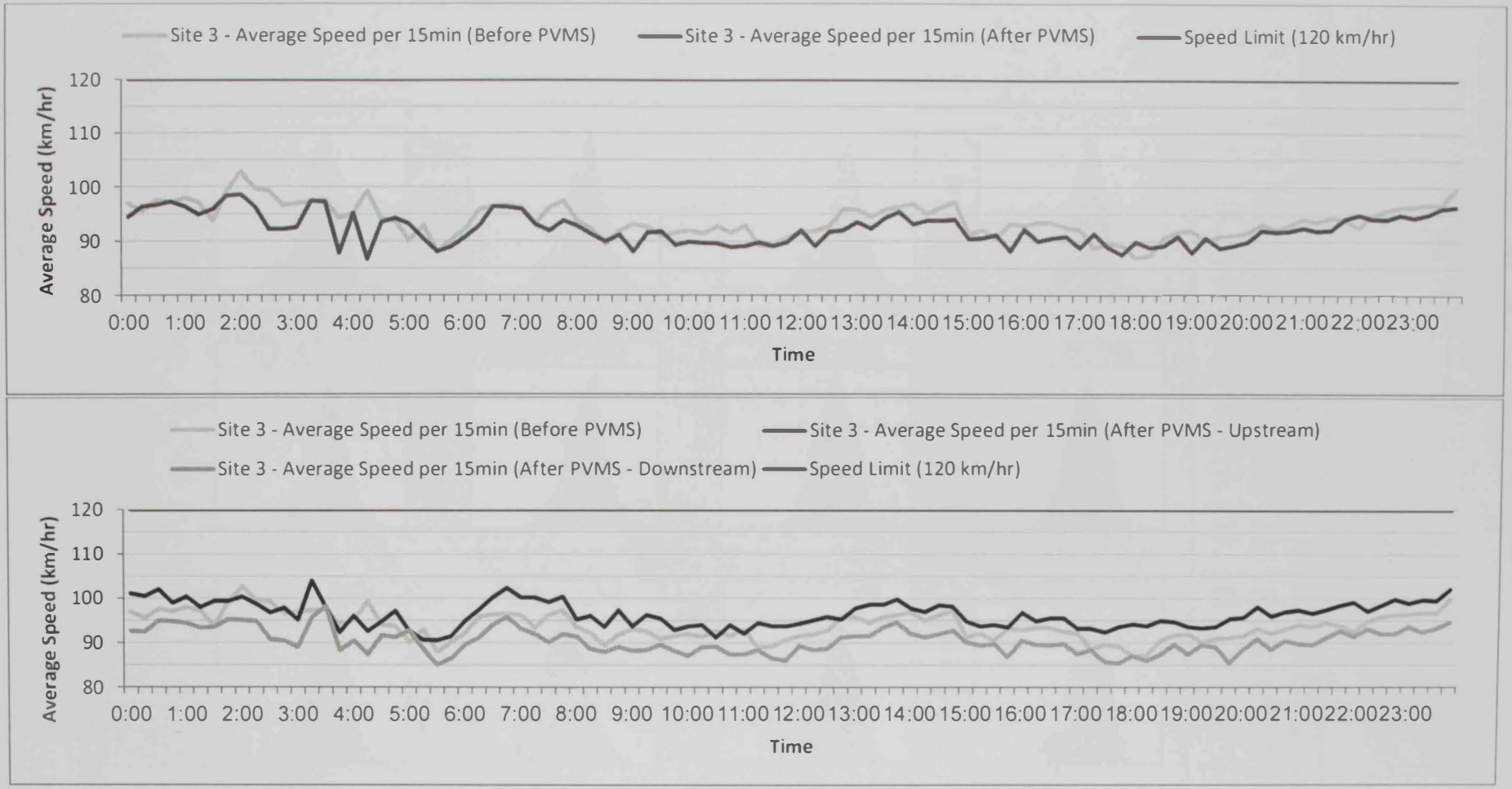
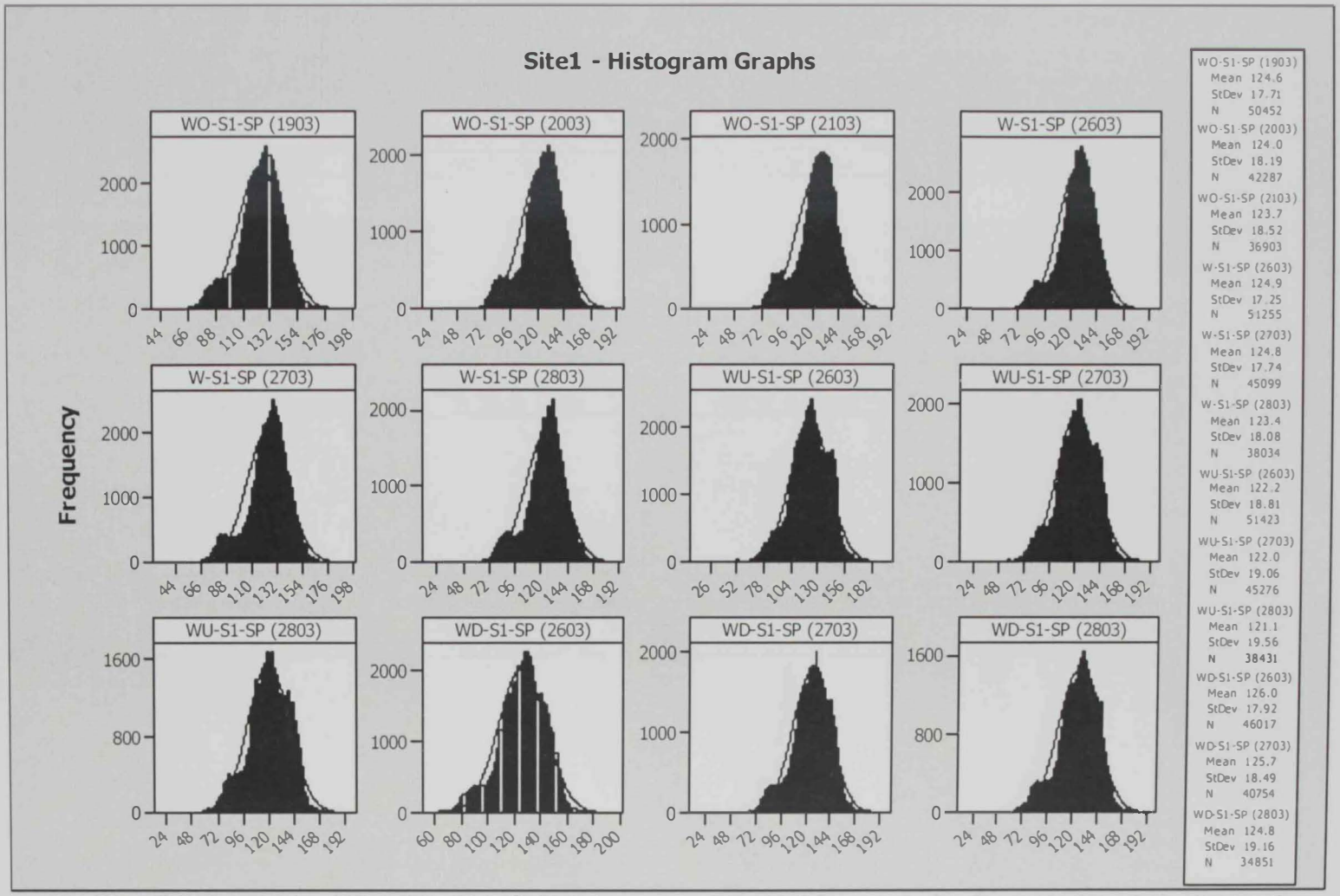
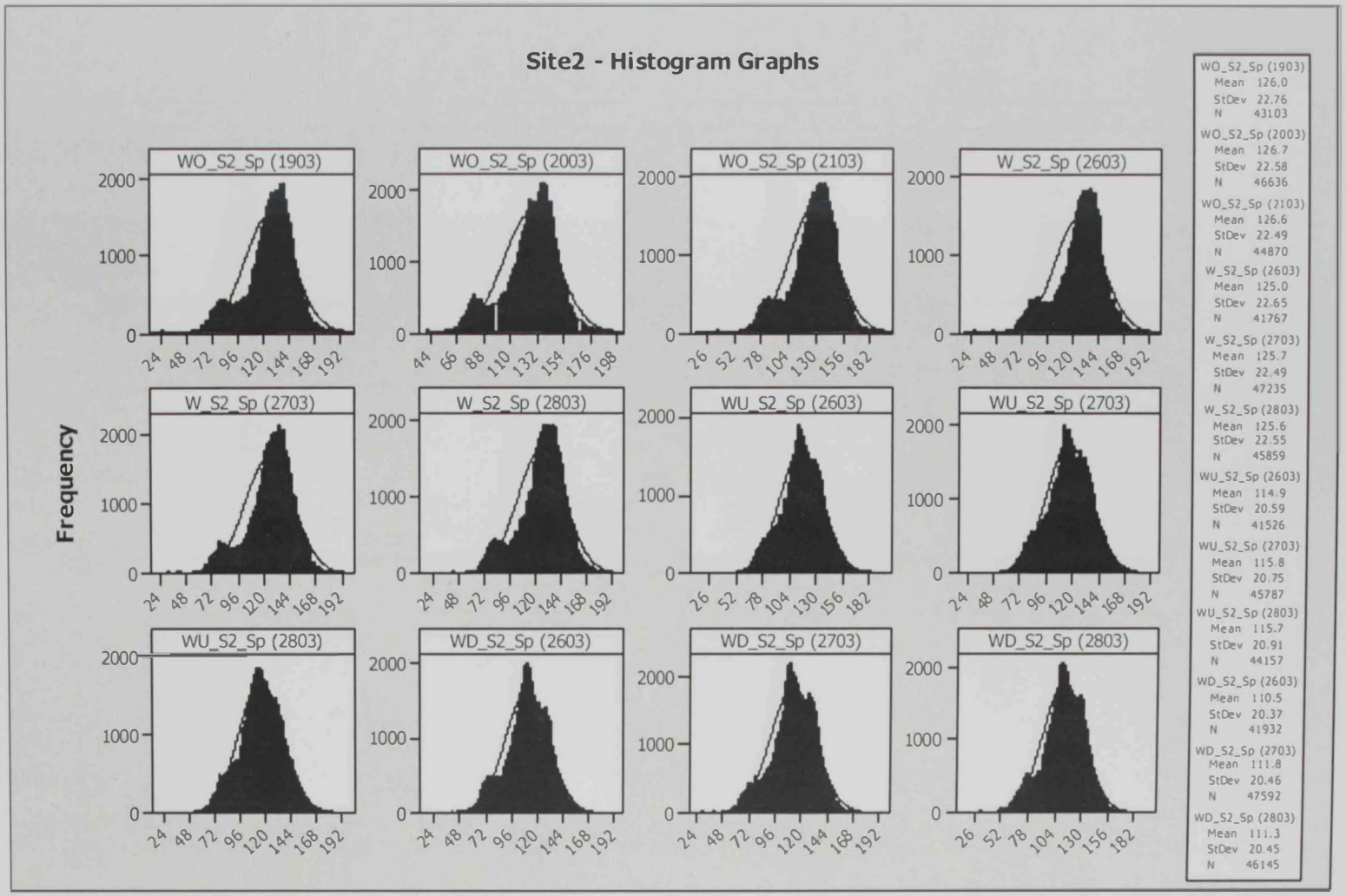


Figure 4.9: Average Speed Profile – Eastern Ring Road, Day 3



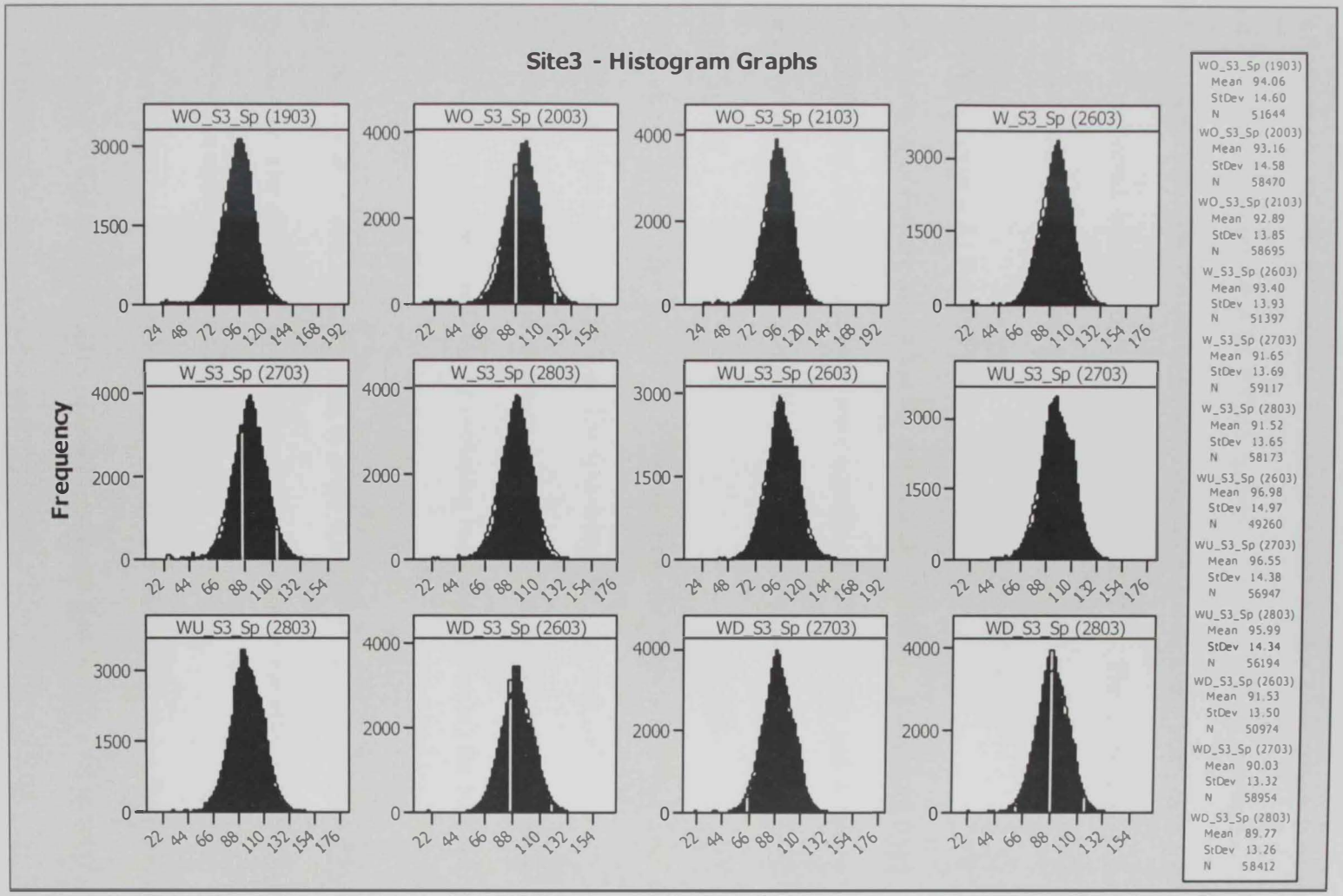
W = With PVMS, WO = Without PVMS, WU = With PVMS/Upstream, WD = With PVMS/Downstream, Sp = Speed, S1 = Site 1 (E11 –Work Zone)

Figure 4.10: Histogram of Speed data – E11 (Work Zone)



W = With PVMS, WO = Without PVMS, WU = With PVMS/Upstream, WD = With PVMS/Downstream, Sp = Speed, S2 = Site 2 (E10 – Raha Beach)

Figure 4.11: Histogram of Speed data – E10 (Al Raha Beach)



W = With PVMS, WO = Without PVMS, WU = With PVMS/Upstream, WD = With PVMS/Downstream, Sp = Speed, S1 = Site 3 (Eastern Ring Road)

Figure 4.12: Histogram of Speed data – Eastern Ring Road

4.3 Speed Statistical Analysis

The effectiveness of the PVMS was evaluated based on the comparison between the before PVMS speeds and the after PVMS speeds. The after PVMS case speeds are the speeds collected when the PVMS was turned on, while the before PVMS case speeds are the speeds collected before implementation of the PVMS. The comparison has been carried at the three sites as follows:

4.3.1 Work Zone – Al Samha Area, E11 Road

i. Comparison of Before and After for All Vehicle Classes – Individual days

In this comparison, all vehicle classes were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table 4.4 shows the average speed on the work zone for both before and after PVMS cases during the data collection period. The following are observed:

- There is no reduction in average speed with the allowable speed limit of 100 km/hr (Posted speed is 80km.hr including margin of 20km/hr) for both before and after cases.
- The average speed for both cases is more than the allowable speed limit by about 25km/hr. The difference in the average speed between the after PVMS and before PVMS is about ±1% (0 km/hr to 1 km/hr).
- The difference in speed between the before and after cases during the three days is due to the higher percentages of class 2 vehicles that have higher average speeds of about 3.5 km/hr in the after case.

- The average speed for the upstream location of the after PVMS case, reduced from 1% to 3% comparing to the before case average speed's due to the existence of a restaurant nearby the upstream location where vehicles were accelerating/decelerating.
- The downstream average speed for the after PVMS case is greater than the average speed of the before case by 1%.

85th percentile speeds

Table 4.4 shows the comparison of 85th percentile speeds between before and after scenarios and for the upstream and downstream locations. It is clear that there is a very small change in the 85th percentile speeds in all scenarios and locations but it is not statistically significant. The mean speed is more than the allowable speed by 25 km/hr. This shows the speeding behavior of drivers.

Table 4.4: MOE's results for Work Zone (All Classes – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	125	142	↑ 0	↑ 0%
	After	125	142		
	Upstream	122	143	↓ 3	↓ 2%
	Downstream	126	144	↑ 1	↑ 1%
SUN	Before	124	142	↑ 1	↑ 1%
	After	125	142		
	Upstream	122	142	↓ 2	↓ 2%
	Downstream	126	145	↑ 2	↑ 1%
Mon	Before	124	142	↓ 0	↓ 0%
	After	123	140		
	Upstream	121	142	↓ 3	↓ 2%
	Downstream	125	144	↑ 1	↑ 1%

Proportions of Speeding Vehicles

The speed distribution was analyzed for before and after scenarios to demonstrate the effectiveness of the PVMS. The basic assumption is that, if the PVMS sign was effective, it would reduce the number of speeding drivers approaching the work zone.

Figure 4.13 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of survey. The figure shows the followings:

- A general trend of relatively high speeds in work zones when the PVMS sign was installed.
- It's noticeable that the numbers of high speed observations are not reduced significantly after installing the PVMS.
- The reduction is about 0.5% for the 150-160 km/hr speeds and 0.1% for the 140-150 km/hr speeds.
- The numbers of speeding drivers in the 120-140 km/hr range are increased after installing the PVMS which means that higher speeds were reduced and shifted back to the speeds of 120-140km/hr which is close to the average speed for both cases before and after PVMS.
- The figure illustrates that the number of vehicles at the lower speeds of 60-120 km/hr are reduced after installing the PVMS.

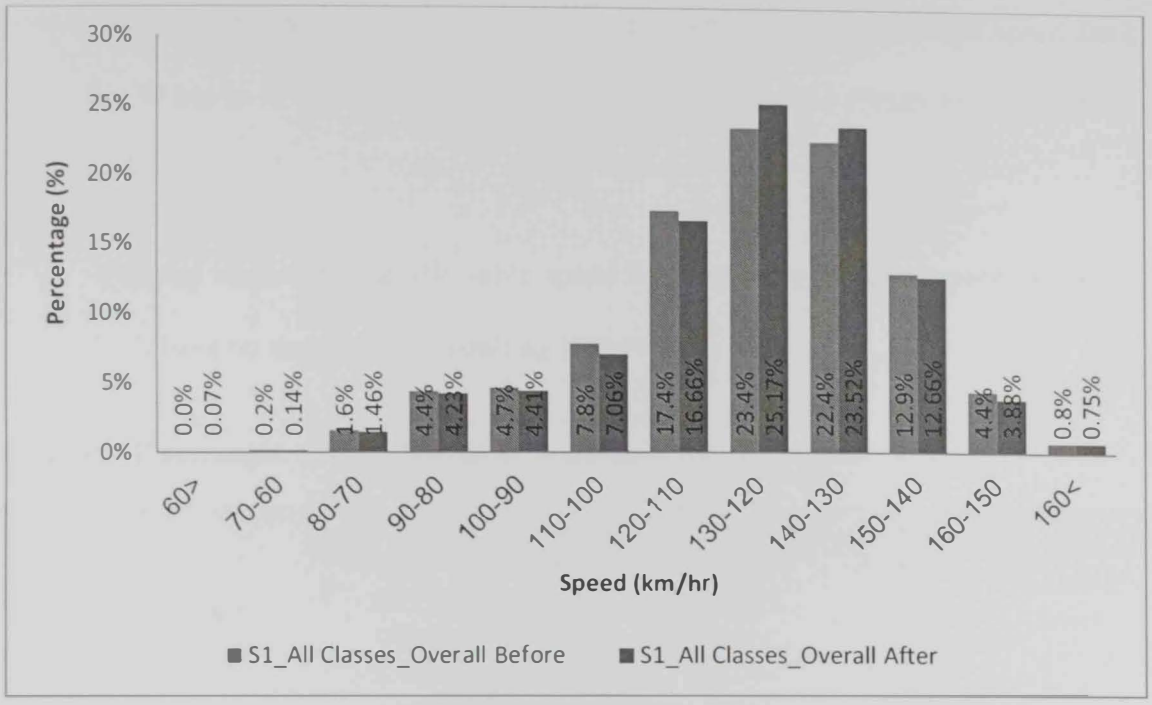


Figure 4.13: Percentages of High Speeds for E11 Road (Work Zone)

Table 4.5 shows the percentages of higher speed vehicles exceeding the allowable speed limit. The overall figures show that:

- About 90% of the vehicles are not complying with the allowable speed limit. The percentage of vehicles exceeding the allowable speed limits for the after PVMS case is compared with the percentage of the vehicles exceeding allowable speed limit for the before PVMS case. In average, the results show that percentage of vehicle exceeding allowable speed limit are more in the before PVMS case and less in the after PVMS case.

- In general, vehicles exceeding the allowable speed limit from more than 0 km/hr to 30 km/hr are reduced after installing the PVMS by about 1% to 2%.

- On the other hand, the numbers of vehicles exceeding the allowable speed limit by 30 km/hr to 40 km/hr are increased after installing the PVMS by about 1% to 2%.

- Vehicles exceeding the allowable speed by more than 40 km/hr over the speed limit have no change after installing PVMS.

Table 4.5: Percentages of High Speeds at Work zone for all classes

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	8%	18%	23%	22%	19%
	After	7%	17%	25%	24%	18%
	Upstream	12%	19%	22%	16%	19%
	Downstream	8%	17%	23%	21%	22%
SUN	Before	8%	18%	23%	22%	17%
	After	7%	16%	25%	24%	18%
	Upstream	12%	19%	21%	16%	19%
	Downstream	8%	17%	22%	21%	23%
Mon	Before	7%	17%	24%	23%	18%
	After	7%	17%	26%	23%	16%
	Upstream	13%	19%	20%	16%	18%
	Downstream	8%	17%	22%	20%	22%

%After < %Before	%After > %Before	%After = %Before

Speed Statistical Test

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table 4.6 indicate that there is a statistically significant difference between the speed means of before PVMS with after PVMS on Saturday and Sunday when the p-value is < 0.005. But t-values indicated that the difference is negative

so the speed means for the before PVMS case is less than the speed means for the after PVMS case. On Monday, the t-value is positive that indicates the speed means for the before PVMS case is greater than the after PVMS case and the p-value is > 0.005 which indicate that there is no statistically significant difference.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

In this case, the upstream and downstream allowable speed is 140km/hr while the allowable speed for the work zone is 100km/hr. accordingly; it's not applicable to compare the difference in average speed between "the upstream or downstream for the after case" with the "before PVMS case".

1 sample t-test: Speed Means for Before/After PVMS and Allowable Speed Limit (100km/hr)

As shown in Table 4.6, there is no statistical difference between the before and after PVMS cases, with the allowable speed limit at 100 km/hr, where the p-value is less than 0.005. The positive t-values indicate that speed means for the before and after PVMS cases are greater than the speed limit. It is clear that t-values are gradually decreased over the days.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Allowable Speed Limit (140km/hr):

The p-values indicate that there is a statistically significant difference in the speed means with the allowable speed (140km/hr). But negative t-values indicate that the upstream and downstream speed means are less than the allowable speed.

Table 4.6: t-Test results for Work zone (All Classes – individual days)

Site 1 – All Classes	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	-3	-7	2
	p-value	0.001	0	0.991
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	-	-	-
	p-value	-	-	-
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	-	-	-
	p-value	-	-	-
1 sample t-test: Speed Means for Before PVMS and Allowable Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_b \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Allowable Speed Limit	t-value	312	271	246
	p-value	1	1	1
1 sample t-test: Speed Means for After PVMS and Allowable Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_a \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Allowable Speed Limit	t-value	327	297	252
	p-value	1	1	1
1 sample t-test: Speed Means for Upstream After PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_u \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Allowable Speed Limit	t-value	-215	-201	-189
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_d \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Allowable Speed Limit	t-value	-168	-157	-148
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

The results for classes 1, 2 and 3 are shown in Appendix F.

Summary

The speed analysis for the E11 Road at the Work Zone site leads to the following observations:

- Drivers in the before PVMS and after PVMS cases are not complying with the allowable speed limit at the Work Zone, which is true for all classes of vehicle. That is due to the presence of posted speed limit signs that were gradually decreased from speed limit of 120km/hr to 80km/hr over short distance at the work zone area.

- In general, there was no reduction in speed mean values after installing the PVMS for all classes of vehicle.

- Class 1 observations are almost similar to the observations for all classes due to the fact that Class 1 forms about 85% of the total.

- The increase in the speed mean values for the after case is due to the increase in Class 2 percentages that have higher speed mean of 3.5 km/hr in the after PVMS case.

- There was no correlation in the speed data at the work zone site before and after installing the PVMS.

- In conclusion, PVMS was not effective in reducing driver speeds at work zone.

4.3.2 E10 at Al Raha Beach Area

i. Comparison of Before and After for All Classes – Individual days

In this comparison, all classes were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table 4.7 shows the average speed at E10 – Al Raha Beach Site for both before and after PVMS cases during the data collection period, the observations are as follow:

- There was a minor reduction of 1% in average speed after installing PVMS. The average speed for both before PVMS and after PVMS is less than the allowable speed limit 140 km/hr (Posted speed is 120km.hr including margin of 20km/hr).
- The average speed for both cases is less than the allowable speed limit by about 15km/hr.

Table 4.7: MOE's results for E10 Road (All Classes – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	126	147	↓ 1	↓ 1%
	After	125	146		
	Upstream	115	135	↓ 11	↓ 9%
	Downstream	111	131	↓ 16	↓ 12%
SUN	Before	127	148	↓ 1	↓ 1%
	After	126	146		
	Upstream	116	137	↓ 11	↓ 9%
	Downstream	112	132	↓ 15	↓ 12%
Mon	Before	127	148	↓ 1	↓ 1%
	After	126	146		
	Upstream	116	137	↓ 11	↓ 9%
	Downstream	111	132	↓ 14	↓ 12%

- The average speeds upstream and downstream for the after PVMS case are reduced by about 9% and 12% respectively compared to the before PVMS average speed.
- The upstream and downstream average speeds are less than the before and after PVMS case due to the nature of these locations. The upstream location is after the Airport Interchange where vehicles are merging with the main road. Therefore, vehicles are accelerating and not reaching the desired speed. The downstream location is nearby Al-Raha Mall access where vehicles are accelerating /decelerating to leave/enter the mall.

85th percentile Speed

The 85th percentile speed is the speed at which it is expected to be close to the allowable speed limit. Table 4.7 shows the 85th percentile comparison between the before and after cases. There is a minor reduction of about 1 km/hr in the 85th percentile speed when PVMS was installed.

Proportions of Speeding Vehicles

The speed distribution has been analyzed for before PVMS mean speeds and after PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figure 4.14 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The figure shows a general trend of relatively high speeds at E10 Road when the PVMS sign was installed. It is noticeable that:

- High speed observations are reduced by about 2.37% after installing the PVMS for the range of 140km/hr to more than 160 km/hr speeds.

- The speeds of less than 60km/hr to 140 km/hr are slightly increased after installing the PVMS which means that high speeds were reduced and shifted back to the lower speeds.

Table 4.8 shows the percentages of higher-speed vehicles exceeding the allowable speed limit. The overall figures show that:

- About 28% of the vehicles are not complying with the allowable speed limit in both cases before PVMS and after PVMS.

- The difference between the percentage of vehicles exceeding the allowable speed limit for the after PVMS case has been compared with the percentage of the vehicles exceeding the allowable speed limit for the before PVMS case.

- In general, vehicles exceeding the allowable speed limit are reduced after installing the PVMS by about 1% to 2%. Also, the vehicles exceeding the allowable speed limit at the upstream and downstream locations after installing PVMS are less than before PVMS.

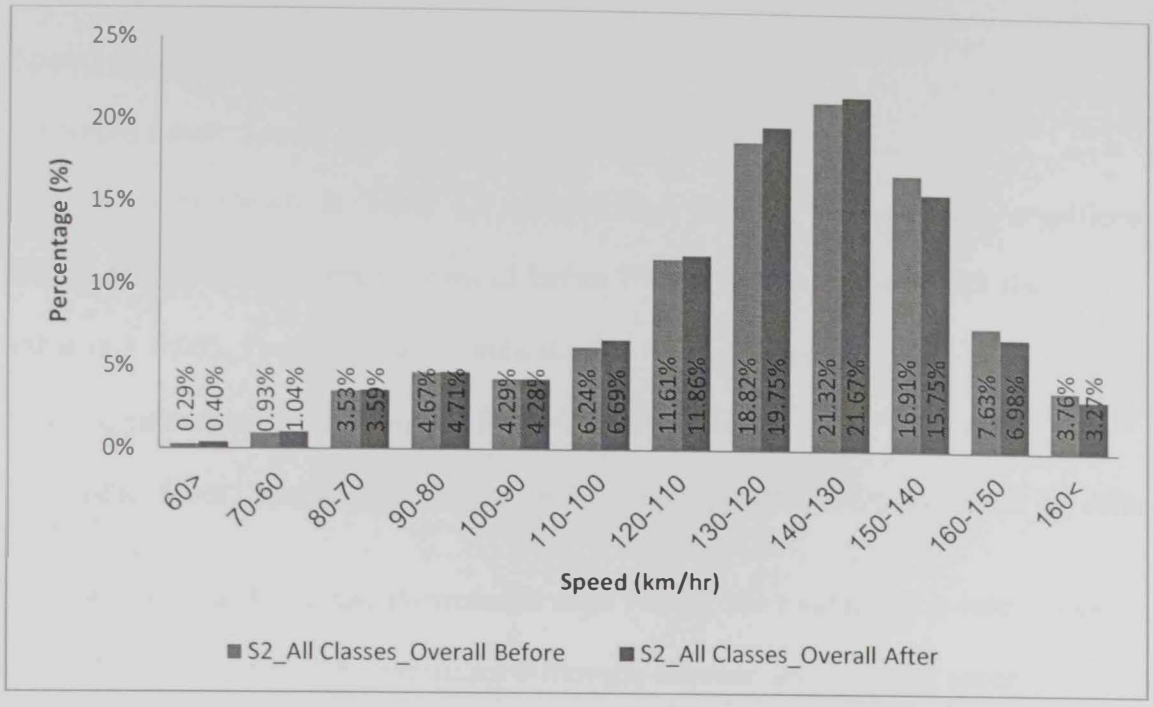


Figure 4.14: Percentages of High Speeds for E10 Road

Table 4.8: Percentages of High Speeds E10 Road for All Classes

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	21%	6%	1%	0%	0%
	After	19%	5%	1%	0%	0%
	Upstream	8%	2%	0%	0%	0%
	Downstream	5%	1%	0%	0%	0%
SUN	Before	22%	6%	1%	0%	0%
	After	20%	6%	1%	0%	0%
	Upstream	9%	2%	0%	0%	0%
	Downstream	6%	1%	0%	0%	0%
Mon	Before	21%	6%	1%	0%	0%
	After	19%	6%	1%	0%	0%
	Upstream	9%	2%	0%	0%	0%
	Downstream	5%	1%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Speed Statistical Test

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table 4.9 indicate that there is no statistically significant difference between the speed means of before PVMS with the after PVMS since the p-value is > 0.005. Positive t-values indicate that the speed means for the before PVMS case is greater than the speed means for the after PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

For both cases upstream and downstream after PVMS, the t-value and p-values indicate that there is no statistically significant difference between the upstream speed means of the after case with the before case. Speed means for the upstream and downstream are less than the speed means for the before case.

1 sample t-test: Speed Means for Before/After PVMS and Allowable Speed Limit (140km/hr)

As shown in Table 4.9, there is a statistically significant difference between the before and after PVMS cases with the allowable speed limit due to the p-value being less than 0.005. The negative t-values indicates that speed means for the before and after PVMS cases are less than the allowable speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Allowable Speed Limit (140km/hr)

There is a statistically significant difference between the upstream and downstream after PVMS case with the introduction of the allowable speed limit due to the p-value being less than 0.005. The negative t-values indicates that speed means for the upstream and downstream after introducing the PVMS are less than the allowable speed limit.

Table 4.9: t-Test results for E10 Road (All Classes – Individual days)

Site 2 – All Classes	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	6	7	6
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	74	76	75
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	104	106	107
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_b \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Allowable Speed Limit	t-value	-128	-128	-126
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_a \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Allowable Speed Limit	t-value	-135	-138	-137
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu u \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Allowable Speed Limit	t-value	-248	-249	-244.3
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Allowable Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_d \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Allowable Speed Limit	t-value	-296	-300	-302
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

The results for classes 1, 2 and 3 are shown in Appendix F.

Summary

The speed analysis for E10 Road at Al Raha Beach (Rural Roads) led to the following observations:

- The speed analysis shows that speed means are reduced after installing PVMS.
- The reduction in speed means after installing PVMS is not statistically significant.
- The mean speeds are less than the posted speed for all classes except Class 3.
- Class 1 observations are almost similar to those for all classes due to Class 1 forming the majority of all vehicles.
- High speed proportions reduced slightly after installing PVMS.
- The upstream and downstream locations have lower speed means after PVMS than the before PVMS case due to the geometric design of the roads where the upstream is close to airport interchange and the downstream is nearby the access to Al Raha Mall.
- In conclusion, PVMS has minor impact of about 1% on reducing speed means but not statistically significant at rural roads of 140 km/hr allowable speed limit.

4.3.3 Eastern Ring Road

i. Comparison of Before and After for All Classes – Individual days

In this comparison, all classes were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table 4.10 shows the average speed at the Eastern Ring Road for both before and after PVMS cases during the data collection period. The following were observed:

- There was a minor reduction of 1% to 2% in average speed after installing the PVMS.
- The average speed for both before PVMS and after PVMS is less than the speed limit 120 km/hr (Posted speed is 100km.hr including margin of 20km/hr).
- The average speed for both cases is less than the speed limit by about 26km/hr.
- The average upstream speed for the after PVMS case is increased about 3% compared to the before PVMS average speed. The downstream after PVMS case is reduced by about 3% compared to the before PVMS average speed.

85^{th} percentile Speed

The 85^{th} percentile speed is the speed which is expected to be close to the speed limit. Table 4.10 shows the 85^{th} percentile comparison between the before and after cases. The 85^{th} percentile speed is less than the speed limit for both before and after PVMS cases. However, there is a minor reduction of about 1km/hr in the 85^{th} percentile speed when PVMS is installed.

Table 4.10: MOE's results for astern Ring Road (All Classes – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	94	108	↓ 1	↓ 1%
	After	93	107		
	Upstream	97	112	↑ 3	↑ 3%
	Downstream	92	106	↓ 3	↓ 3%
SUN	Before	93	107	↓ 2	↓ 2%
	After	92	105		
	Upstream	97	111	↑ 3	↑ 4%
	Downstream	90	104	↓ 3	↓ 3%
Mon	Before	93	106	↓ 1	↓ 2%
	After	92	105		
	Upstream	96	110	↑ 3	↑ 3%
	Downstream	90	104	↓ 2	↓ 3%

Proportions of Speeding Vehicles

The speed distribution has been analysed for the mean speeds before PVMS and after PVMS to demonstrate the effectiveness of the PVMS. Figure 4.15 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of the speed survey. The figure show a general trend of relatively high speeds at the Eastern Ring Road when the PVMS sign was installed. It is noticeable that:

- The observations of higher speeds are reduced significantly after installing the PVMS. The reduction is about 4.05% for the band of 90km/hr to more than 160 km/hr speeds.

- The observations of speeds of less than 60km/hr to 140 km/hr are slightly increased after installing the PVMS.

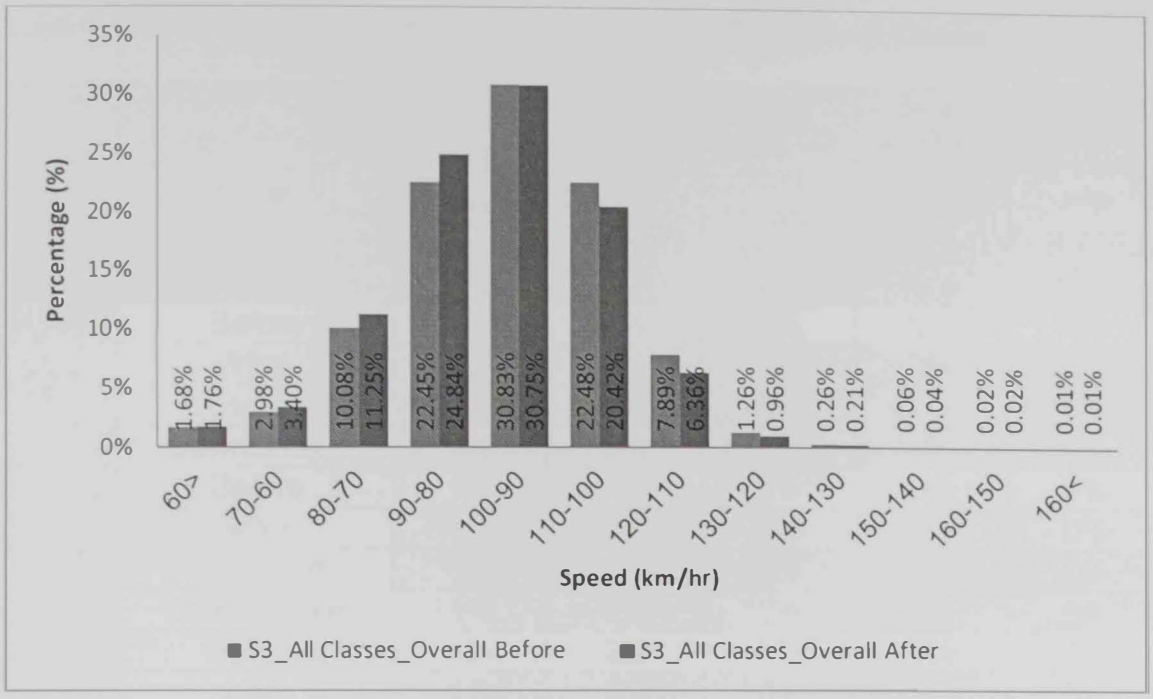


Figure 4.15: Percentages of High Speeds for Eastern Ring Road

Table 4.11 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 2% of the vehicles are not complying with the speed limit both in the cases before PVMS and after PVMS.

The difference between the percentage of vehicles exceeding speed limits for the after PVMS case has been compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

- In general, vehicles exceeding the speed limit are reduced after installing the PVMS by about 1% to 2%.

- The vehicles exceeding the speed limit at the upstream are more than the before the PVMS case. On the other hand, the vehicles exceeding the speed limit at the downstream after PVMS are less than the before PVMS case.

Table 4.11: Percentages of High Speeds at Eastern Ring Road for All Classes

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	2%	0%	0%	0%	0%
	After	1%	0%	0%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%
SUN	Before	1%	0%	0%	0%	0%
	After	1%	0%	0%	0%	0%
	Upstream	3%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%
Mon	Before	1%	0%	0%	0%	0%
	After	1%	0%	0%	0%	0%
	Upstream	3%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Speed Statistical Test

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table 4.12 indicate that there is no statistically significant difference between the speed means before the PVMS and after the PVMS since the p-value is > 0.005. Positive t-values indicate that the speed means for the before PVMS case is greater than the speed means for the after PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

The comparison of the upstream mean speed after PVMS compared with the before PVMS, shows there is a statistically significant difference between the speed means, since the p-value is < 0.005. Negative t-values indicate that the speed means for the before PVMS case is less than the speed means for the after PVMS case. For the

downstream case looking at after the PVMS compared with before the PVMS, the t-value and p-values indicate that there is no statistically significant difference and speed means for the downstream are less than the speed means for the before case.

1 sample t-test: Speed Means for Before/After PVMS and Allowable Speed Limit (120km/hr):

As shown in Table 4.12, there is a statistically significant difference in speeds between the before and after PVMS cases with the allowable speed limit with a p-value of less than 0.005. The negative t-values indicates that speed means for the before and after PVMS cases are less than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Allowable Speed Limit (120km/hr):

There is a statistically significant difference between the upstream and downstream cases after the PVMS with the allowable speed limit with a p-value of less than 0.005. The negative t-values indicate that speed means after the PVMS both upstream and downstream are less than the allowable speed limit.

Table 4.12: t-Test results for Eastern Ring Road (All Classes – Individual days)

Site 3 – All Classes	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	7	18	17
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	-31	-39	-37
	p-value	0	0	0
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	29	38	39
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Allowable Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_b \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Allowable Speed Limit	t-value	-404	-445	-474
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Allowable Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_a \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Allowable Speed Limit	t-value	-433	-504	-503
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Allowable Speed Limit (120km/hr) Null Hypothesis H_o:$\mu u \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Allowable Speed Limit	t-value	-341	-389	-397
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Allowable Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_d \leq$ Allowable Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Allowable Speed Limit	t-value	-476	-546	-551
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

The results for classes 1, 2 and 3 are shown in Appendix F.

Summary

The speed analysis for the Eastern Ring Road (Urban Roads) site leads to the following conclusions:

- The speed analysis shows that the speed means are reduced after installing PVMS.
- The reduction in speed means after installing PVMS though is not statistically significant.
- The mean speeds are less than the posted speed for all vehicle classes except Class 3
- Class 1 observations are virtually equal to the observations for all classes due to the very high proportion of Class 1 vehicles in the traffic mix.
- The vehicle classes percentages were almost identical for the before PVMS case and after PVMS case.
- High speed proportions reduced slightly after installing PVMS.
- The speed means for both before and after PVMS cases are less than the allowable speed limit by about 25km/hr.
- Upstream after implementing PVMS mean speeds are higher than the before PVMS case, while downstream after installing the PVM speed means are lower than before the PVMS.
- In conclusion, PVMS has a minor impact of about 1-2% on reducing speed means but is not statistically significant on urban roads of 120 km/hr allowable speed limit.

4.4 Driver Satisfaction Survey Analysis

As discussed earlier, the driver surveys were conducted to assess driver opinion on the PVMS performance and the effectiveness of the PVMS. The driver's survey analysis is summarized as follows:

4.5.1 Driver's Characteristics

The characteristics of the respondents in terms of their gender, age, education level and license validity duration are shown in Figure 4.16.

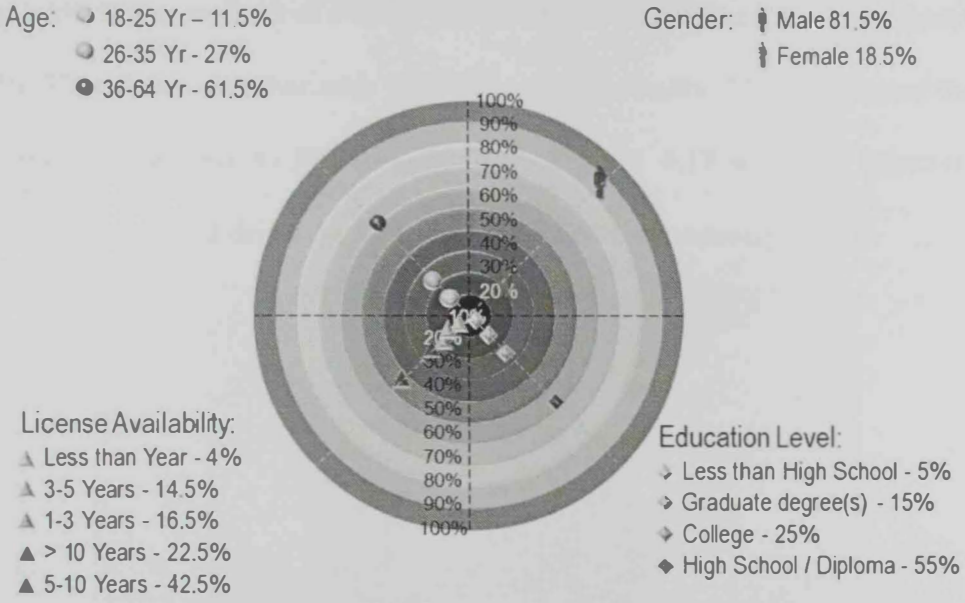


Figure 4.16: Driver Characteristics of the Surveyed Respondents

The driver's characteristics were firstly analysed to make better assumptions and to better understand the statistical results that the data would yield. Overall, more males (n=163) than females (n=37) participated in the survey, resulting in a sample population of 81.5% males and 18.5% females. In terms of age distribution, 61.5% were between 26-35 years of age, 27% between 18-25 years of age while 11.5% represented those over 36 years of age. The education level distribution indicated that those with high school/diploma constituted

55%, college 25%, graduate degree 15% and without high school certificate 5%. The validity of license duration yielded the following; 22.5% with more than 10 years, 42.5% with 5-10years, 14.5% 3-5years, 16.5% with 1-3years and finally 4% with less than a year.

4.5.2 Frequency of Driving on Abu Dhabi Roads and awareness of PVMS

Most respondents indicated that they were frequent users of Abu Dhabi case study roads with daily users comprising 69.5% or weekly 25.5%, monthly 3.5% and less than monthly 1.5%. On awareness of PVMS, the results indicated that 2.5% have never heard of PVMS, 2% not very familiar with 17% indicating neutrality. 37.5% indicated that they were fairly familiar and 41.5% very familiar. Figures 4.17 and 4.18 illustrated the frequency of driving and driver awareness of the PVMS respectively.

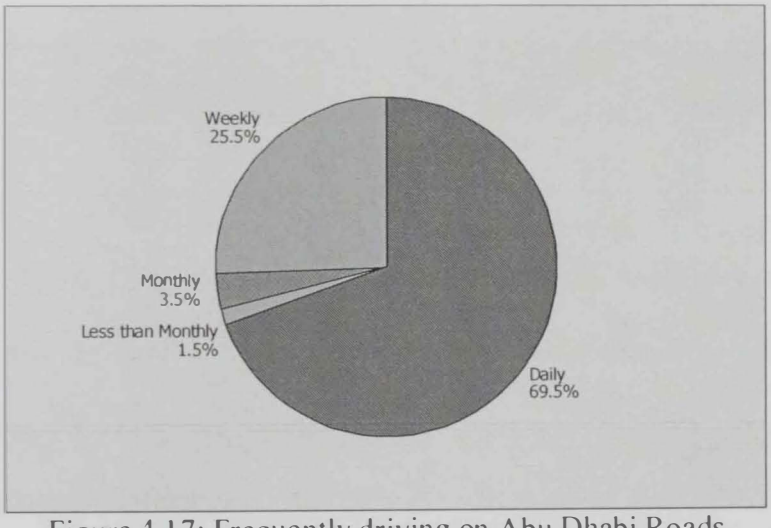


Figure 4.17: Frequently driving on Abu Dhabi Roads

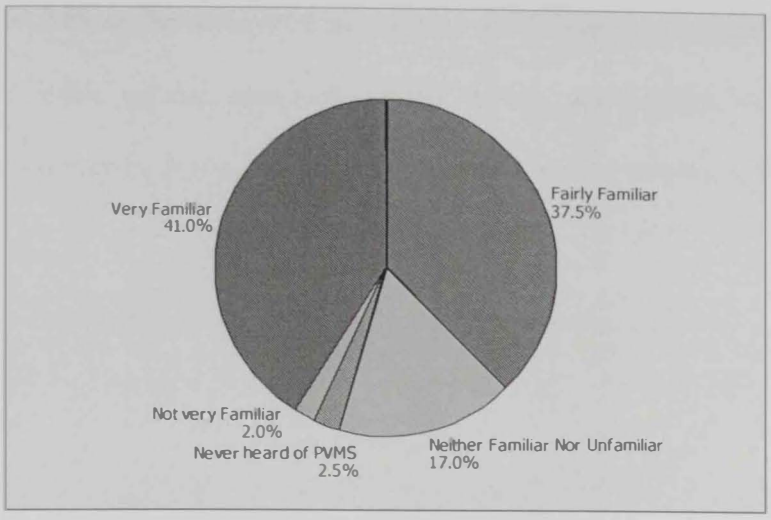


Figure 4.18: Driver Awareness of PVMS

Age Analysis

Table 4.13 illustrates the drivers' responses on frequency of driving on Abu Dhabi (AD) roads. Almost 70% of the drivers are driving daily on AD roads.

Table 4.13: Responses from different Age Groups – Frequently driving on AD roads

Age Group	Total %	Frequency of Driving on Abu Dhabi Roads			
		Daily	Weekly	Monthly	Less than Monthly
18-25 Years	27.0%	19%	7%	1%	0%
26-35 Years	61.5%	41%	17%	3%	2%
36-65 Years	11.5%	10%	2%	0%	0%

Table 4.14 and Figure 4.19 illustrate the drivers' responses on familiarity of PVMS. Most of the age groups are familiar with the PVMS. Most of respondents are familiar with PVMS, However, 16% of driver responses of age groups 18-25 years and 26-35 years are neither familiar nor unfamiliar.

Table 4.14: Responses from different Age Groups in (%) – Familiarity of PVMS

Age Group	Total %	Are you familiar with what PVMS are?				
		Never heard of them	Not Familiar	Neither Familiar Nor Unfamiliar	Familiar	Very Familiar
18-25 Years	27.0%	2%	0%	8%	12%	6%
26-35 Years	61.5%	1%	2%	8%	20%	31%
36-65 Years	11.5%	0%	0%	1%	6%	5%

Familiarity of PVMS analysis shows that most of daily, weekly, monthly and less than monthly drivers drive on AD roads of all age groups are familiar with the PVMS. However, only 5 driver (3 driving daily and 2 driving weekly) responses are not familiar with PVMS.

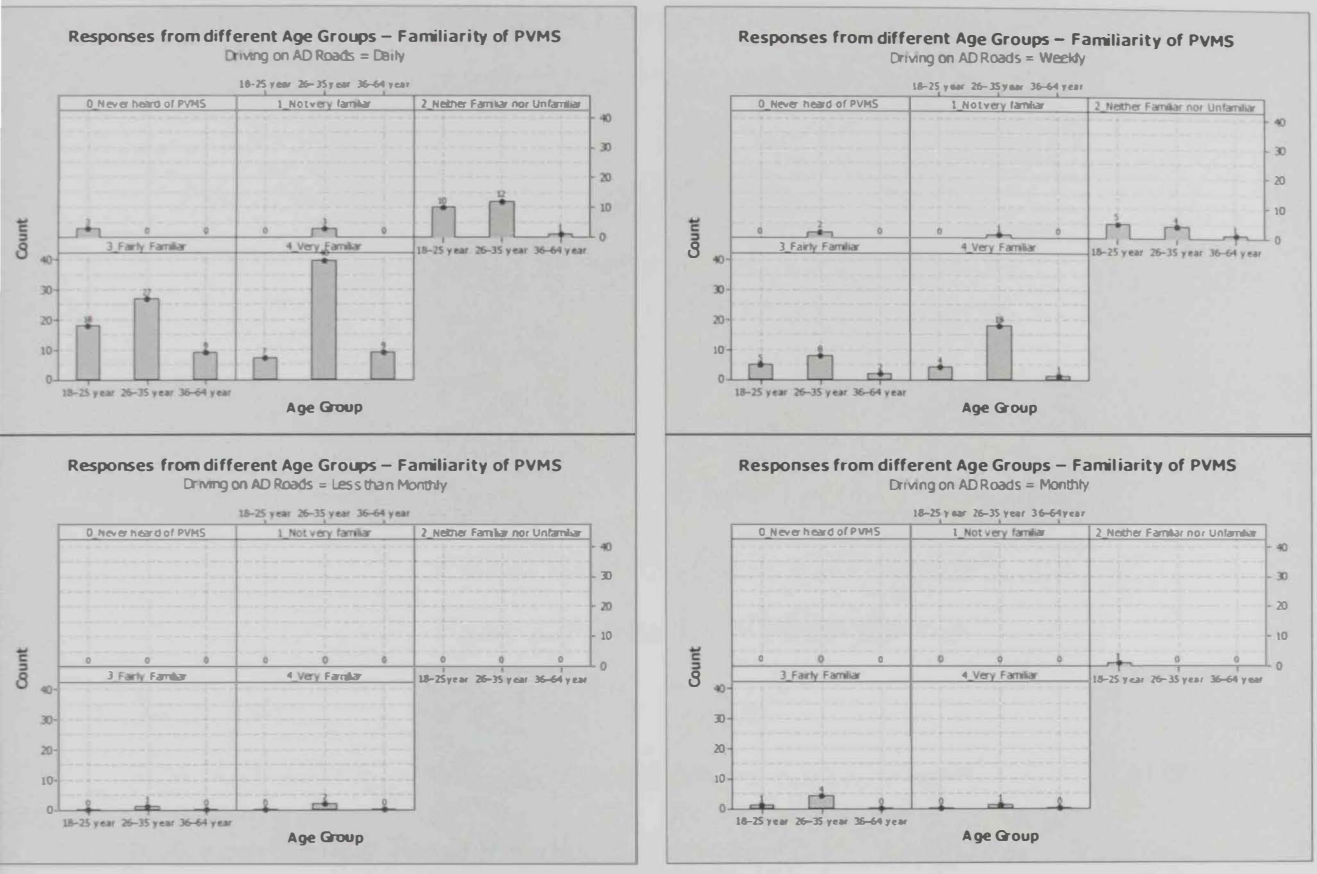


Figure 4.19: Driver Awareness of PVMS, driving on AD roads vs age groups

4.5.3 Accuracy of the PVMS Message

Respondents were asked about the PVMS message accuracy. The results, as shown in Figure 4.20, indicated that 72.5% of the drivers declared that the PVMS messages are accurate, 17% of drivers stated PVMS message were not accurate and 10.5% of drivers said sometimes PVMS Message are accurate and sometimes they are not.

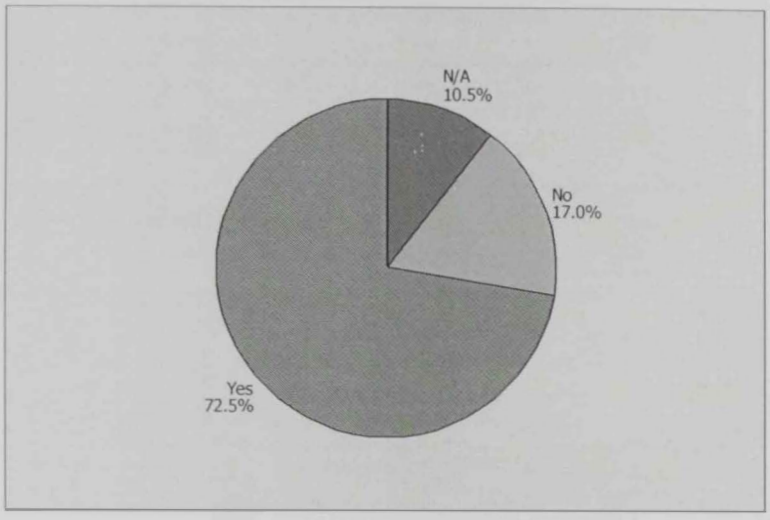


Figure 4.20: Accuracy of PVMS Message

Age Analysis

Table 4.15 and Figure 4.21 illustrate the drivers' responses on the accuracy of PVMS's posted information. The analysis shows that:

- For age group 18-25 years, 34 drivers agree on PVMS accuracy while 8 drivers disagree as shown in Figure 4.21.

- For age group 26-35 years, 93 drivers stated PVMS messages are accurate, while 22 drivers stated PVMS messages are not accurate. 8 drivers responded that the accuracy of PVMS cannot be relied on since sometime the messages are accurate and other times are not accurate as shown in Figure 4.21.

- For ager group 36-64, 2% of driver responses stated that PVMS messages are accurate while 1% driver responses stated that PVMS messages are not accurate as shown in Table 4.15.

Table 4.15: Responses from different Age Groups – Accuracy of PVMS

Age Group	Total %	Accuracy of PVMS?		
		Yes	No	Not Applicable
18-25 Years	27.0%	17%	4%	6%
26-35 Years	61.5%	47%	11%	4%
36-65 Years	11.5%	2%	1%	0%

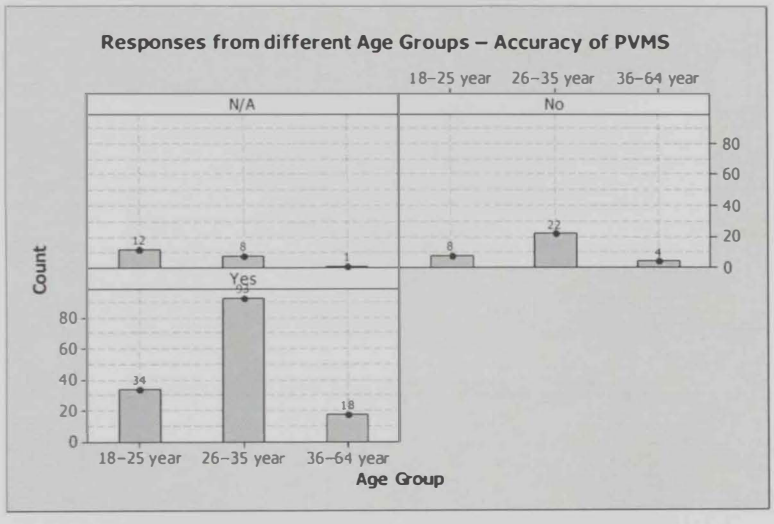


Figure 4.21: Accuracy of PVMS Message vs Age Groups

4.5.4 Appearance and the reasons for difficulty in reading the PVMS message

Respondents were asked about difficulties with the PVMS visual appearance and were requested to rank six reasons of difficulty in reading the PVMS message. The driver feedback on the PVMS appearance, as shown in Figure 4.22 and Figure 4.23, was as follows; very difficult- 1.5%, difficult- 2%, moderately difficult- 26%, easy- 40.5% and very easy-30%. Overall, 70.5 % considered the PVMS appearance is easy to read while 3.5% considered the PVMS appearance is difficult for reading.

In terms of establishing the difficulty in reading the PVMS messages, 23.9% of the drivers indicated that their views are often blocked by traffic, 17.2% were related to inappropriate location, 15.7% were worried with the frequent change of messages, 15.5% were concerned with lack of frequent updates, while 14% were concerned with the size of lettering and 13.8% were concerned with the length of the messages – too long.

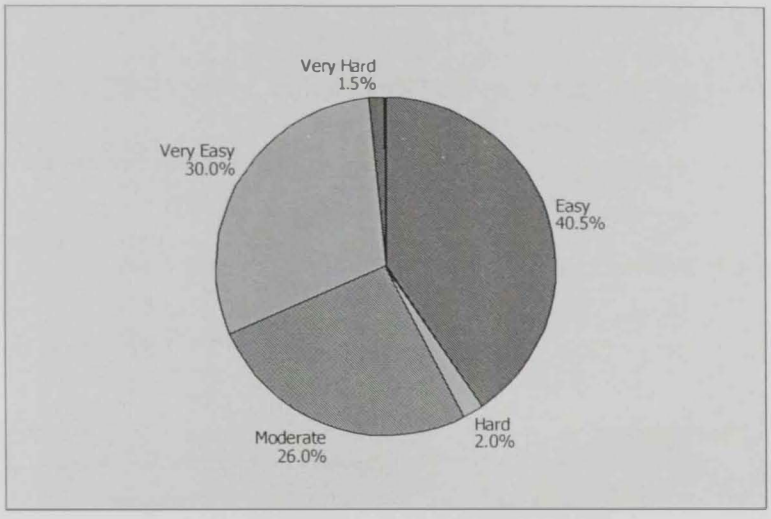


Figure 4.22: PVMS Appearance Difficulty

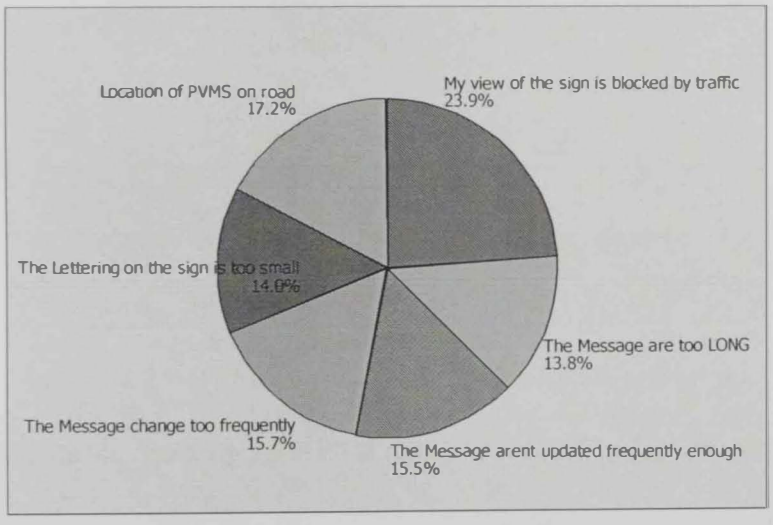


Figure 4.23: PVMS Appearance Difficulty Reasons Ranking

Age Analysis

Figure 4.24 illustrates the drivers' responses on the PVMS appearance difficulty. The analysis shows that:

- For age group 18-25 years, only 4 drivers stated that it's hard to see the PVMS, while 38 driver's felt it to be easy to see the PVMS.

- For age group 26-35 years, majority (87 drivers) stated it's easy to see the PVMS sign, as shown in Figure 4.24.

- For age group 36-65 years, drivers responses varied between moderate, easy and very easy to see the PVMS sign.

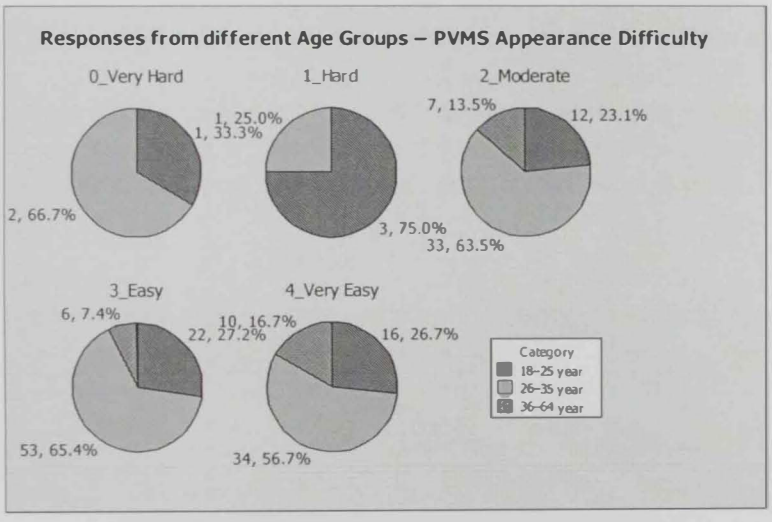


Figure 4.24: PVMS Appearance Difficulty vs Age group

Table 4.16 illustrate the ranking of PVMS appearance difficulty reasons. The analysis shows that:

- All age groups agreed that "My view of the sign is blocked by traffic" is the main reason for PVMS appearance difficulty.

Table 4.16: PVMS appearance difficulty reasons ranking according to age groups

Age Group	PVMS Appearance Difficulty Reasons Ranking					
	1st Rank	2nd Rank	3rd Rank	4th Rank	5th Rank	6th Rank
18-25 Years	My view of the sign is blocked by traffic	The Message aren't updated frequently enough	Location of PVMS on road	The Message are too LONG	The Message change too frequently	The Lettering on the sign is too small
26-35 Years	My view of the sign is blocked by traffic	Location of PVMS on road	The Message aren't updated frequently enough	The Message change too frequently	The Lettering on the sign is too small	The Message are too LONG
36-65 Years	My view of the sign is blocked by traffic	The Message change too frequently	The Message are too LONG	Location of PVMS on road	The Lettering on the sign is too small	The Message aren't updated frequently enough

4.5.5 Reading PVMS Messages and the PVMS Messages subjects

The driver feedback on reading the PVMS messages, as shown in Figure 4.25, indicated that 54% read them always or most of the time, with 44.5% and 1.5% respectively sometimes or rarely reading them. On the message subjects as shown in Figure 4.26, many drivers 33.1% and 27.8% indicated that road closure and/or detour and construction or maintenance were easily read. Accidents and and/or road hazard warnings and weather related advisory messages were easily read and understood by 19.2% and 18.7% respectively.

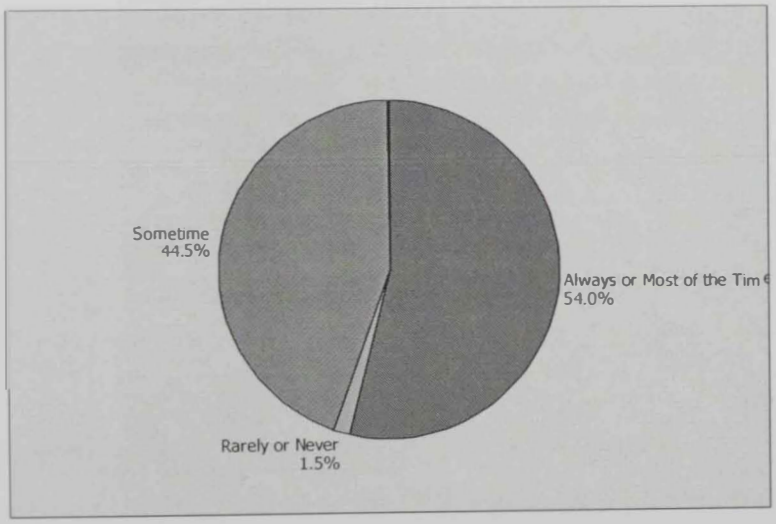


Figure 4.25: Reading PVMS Message

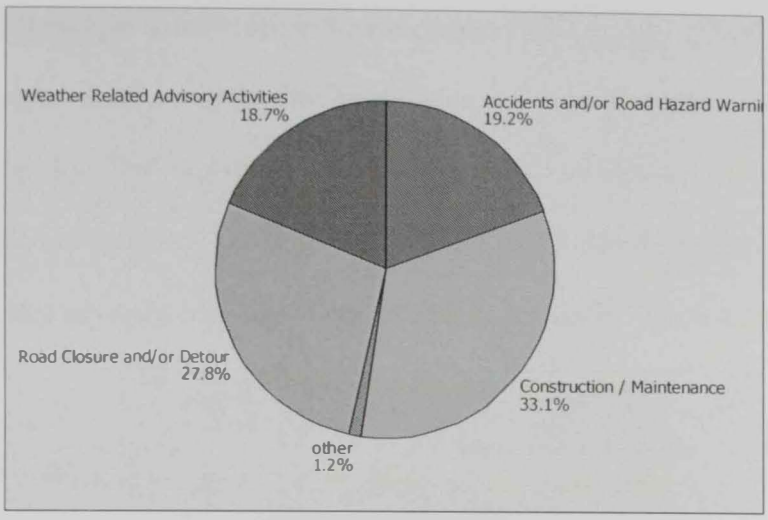


Figure 4.26: PVMS Message Subjects

Age Analysis

Figure 4.27 illustrates the drivers' responses on reading PVMS message. The figure shows that:

- For age group 18-25 years, only 2 drivers are rarely or never read the PVMS message.
- For age group 26-35 years, only one driver was not reading the PVMS message.
- For age group 36-64 years, most of drivers are reading PVMS always and sometimes.

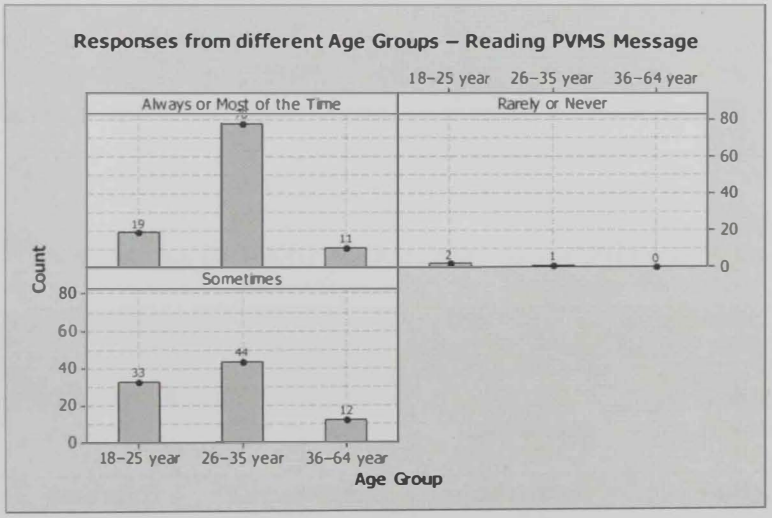


Figure 4.27: PVMS Message Subjects

4.5.6 PVMS Message Information to be displayed

Respondents were asked to rank the importance of the information which can be displayed on PVMS. The responses were as follows: accidents and/or road hazard warnings, 29.2%, construction / maintenance, 25.2%, road closure and/or detour, 24.0% and weather related advisory messages with 20.5%, as shown in Figure 4.28.

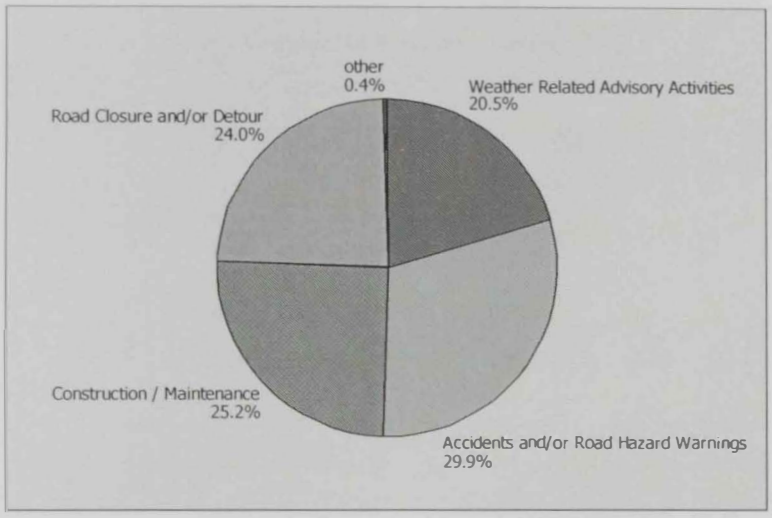


Figure 4.28: PVMS Message Information Importance

Age Analysis

Table 4.17 illustrates the drivers' responses on reading PVMS message information importance. The table shows that:

- All age groups agreed on the importance ranking of PVMS subjects as shown in Table 4.17.

Table 4.17: PVMS appearance difficulty reasons ranking according to age groups

Age Group	PVMS Message Information Importance				
	Most Important				Less Important
18-25 Years	Accident 31%	Construction 25%	Lane Closure 23%	Weather 21%	Other 0%
26-35 Years	Accident 30%	Construction 25%	Lane Closure 25%	Weather 20%	Other 0%
36-65 Years	Accident 30%	Construction 27%	Lane Closure 22%	Weather 19%	Other 1%

4.5.7 Evaluation of PVMS

In evaluating the effectiveness of the PVMS, 74% of the respondents strongly agreed or agreed that the implementation of PVMS has been positive, while only 3% of drivers indicated that they strongly disagreed that the implementation of PVMS had positive, effects as shown in Figure 4.29.

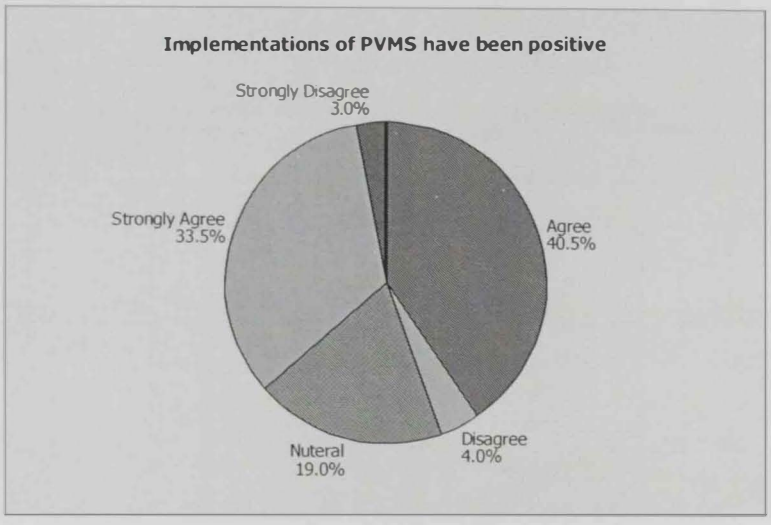


Figure 4.29: PVMS Message Implementation is Positive

Age Analysis

Figure 4.30 illustrates the drivers' responses on the implementation of PVMS taking into consideration the variables of age groups and familiarity of PVMS. The figure shows that:

- In the age group 18-25 years, four drivers who are familiar with PVMS strongly disagreed that "implementation of PVMS is positive".
- There are drivers who are familiar with PVMS but did not agree that "implementation of PVMS is positive".
- Some drivers who are not familiar with PVMS still agreed that the implementation of PVMS is positive.

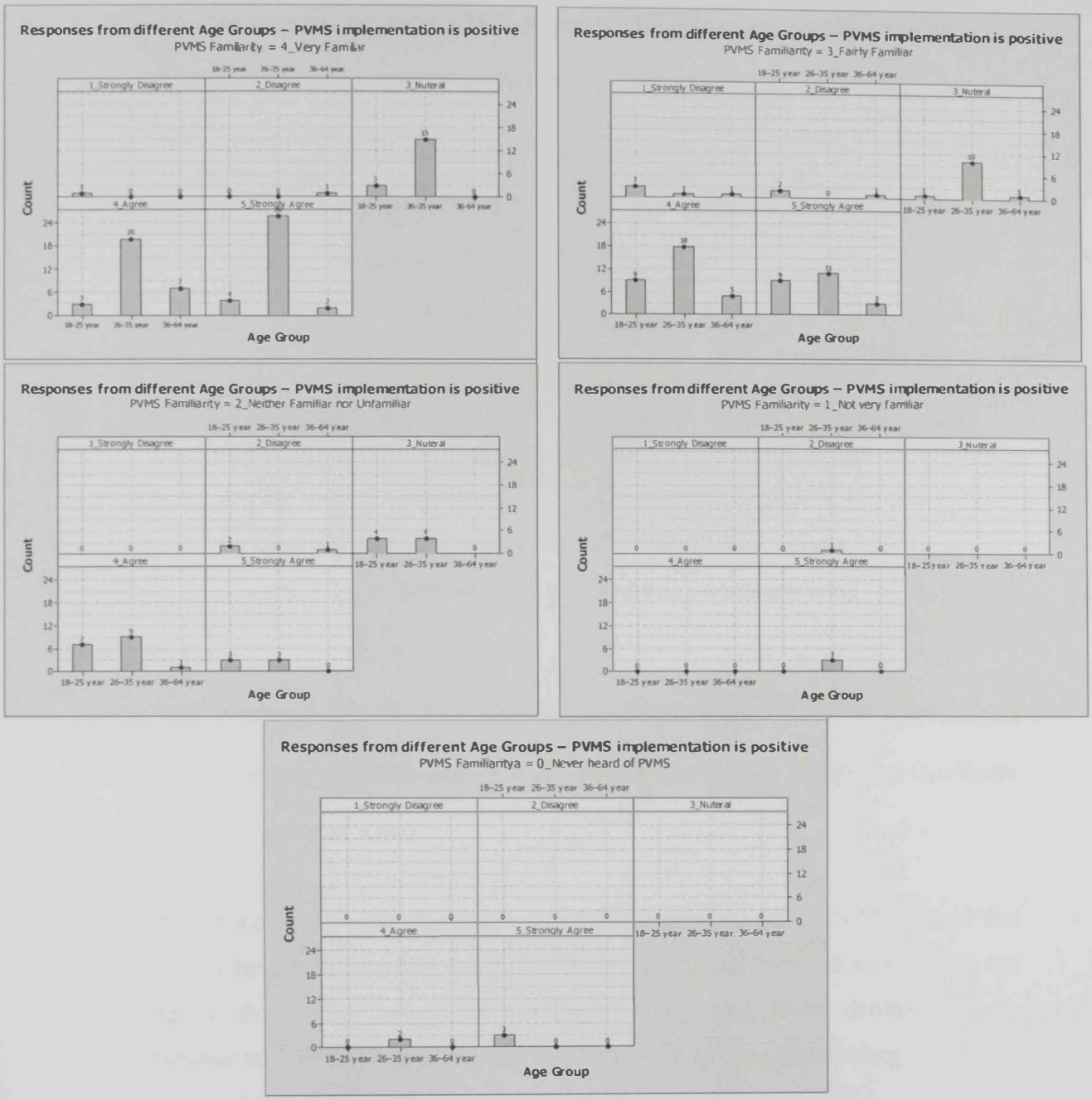


Figure 4.30: PVMS Implementation is Positive, Age group vs Familiarity of PVMS

63.5% of respondents agreed that PVMS had personally helped them while traveling while only 7% of the respondents disagreed as shown in Figure 4.31.

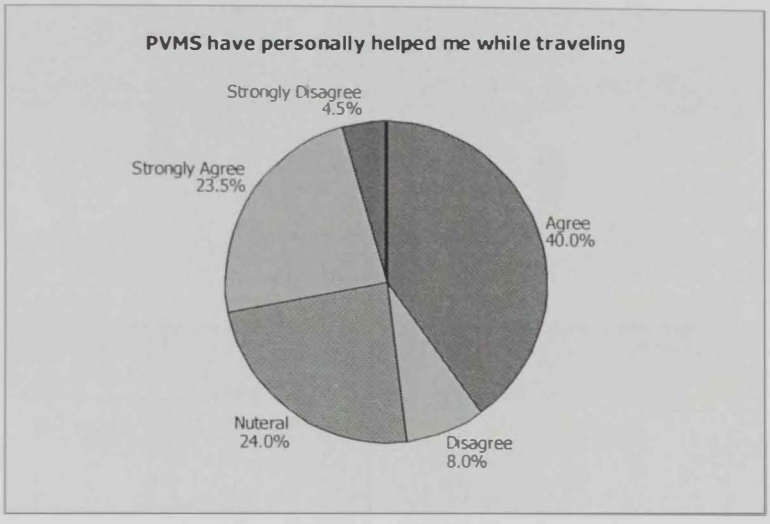


Figure 4.31: PVMS Message helped drivers while traveling

Age Analysis

Figure 4.32 illustrates the drivers' responses on whether the PVMS message helped drivers while traveling taking in consideration the variables of age groups and familiarity of PVMS. The figure shows that:

- Age group 18-25 years, three drivers who had never heard of PVMS agreed that PVMS helped them while traveling. Drivers who are familiar with PVMS are agreed that PVMS helped them while traveling. Only three drivers who are familiar with PVMS disagreed that PVMS helped them while traveling.

- Age group 26-35 year, two drivers who had never heard of PVMS agreed that PVMS helped them while traveling. Drivers who are familiar with PVMS agreed that PVMS helped them while traveling (31 drivers). Only four drivers who are familiar with PVMS disagreed that PVMS helped them while traveling.

- Age group 36-65 year, most of drivers who are familiar with PVMS are agreed that PVMS helped them while traveling.

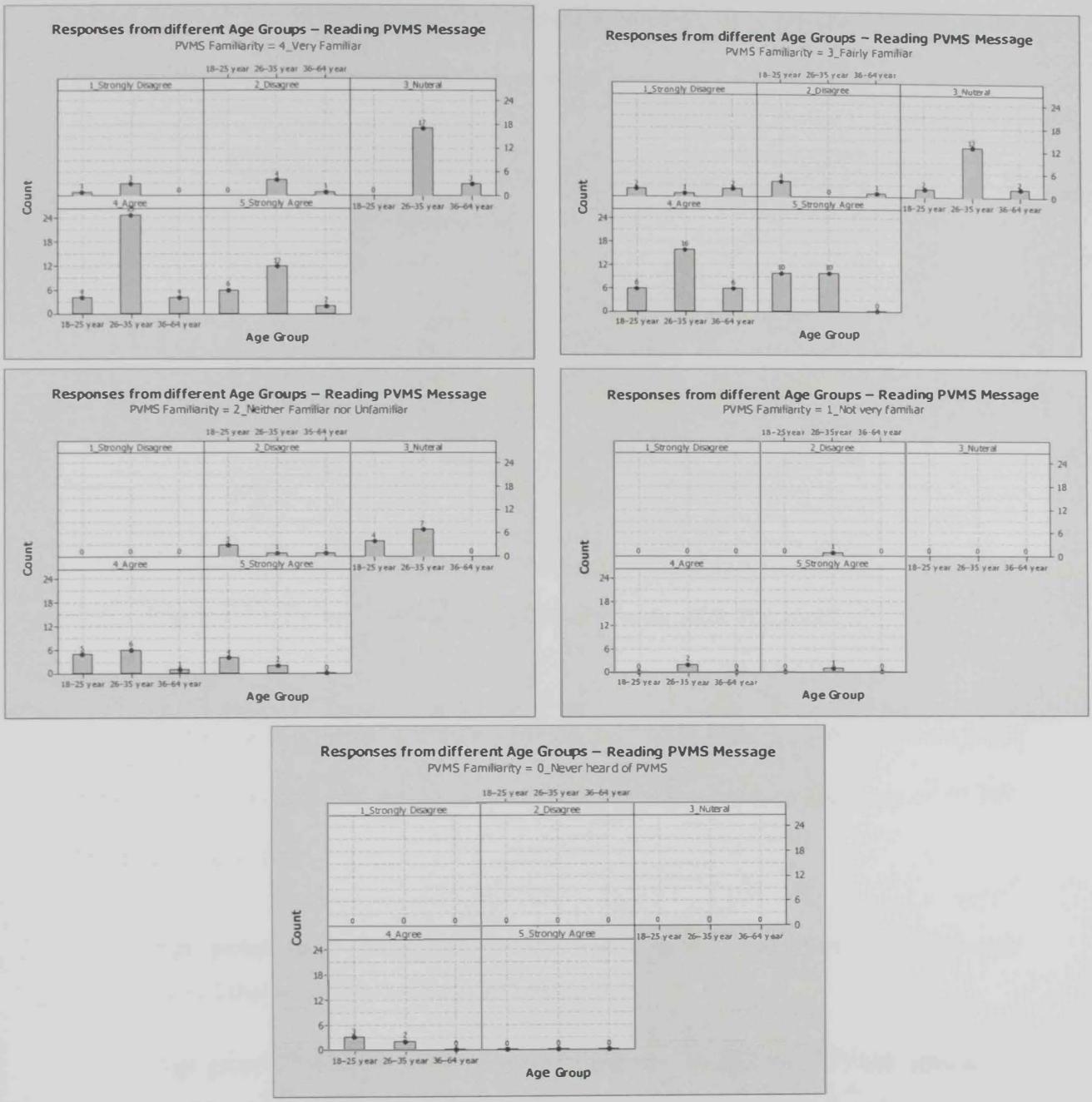


Figure 4.32: PVMS Message helped drivers while traveling, Age group vs Familiarity of PVMS

About 60% of the drivers agreed that roadways are safer as a result of PVMS while 14.5% of the respondents disagreed, as shown in Figure 4.33.

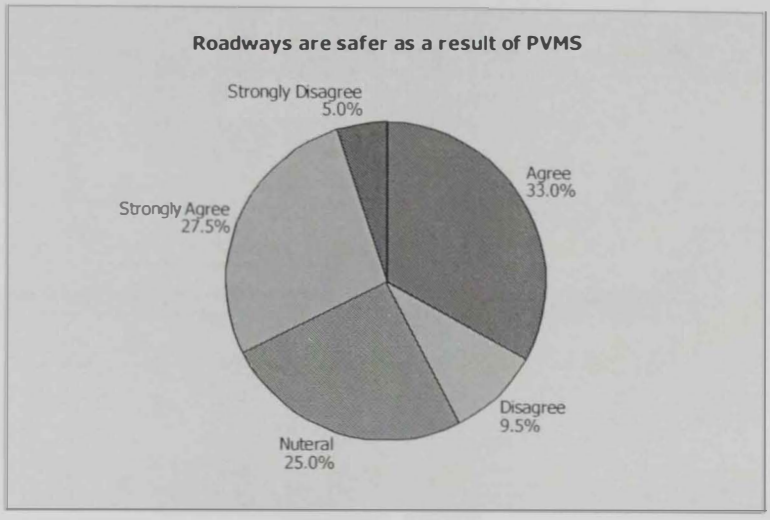


Figure 4.33: Driver's responses on Roadways are safer as a result of PVMS

Age Analysis

Figure 4.34 illustrates the drivers' responses on the PVMS message helped drivers while traveling taking into consideration the variables of age groups and familiarity of PVMS. The figure shows that:

- Age group 18-25 years, two drivers who had never heard of PVMS strongly agreed that roadways are safer as a result of PVMS.
- Age group 26-35 year, most of drivers who are familiar with PVMS agreed that roadways are safer as a result of PVMS.
- Age group 36-65 year, some drivers who are familiar with PVMS agreed that roadways are safer as a result of PVMS.

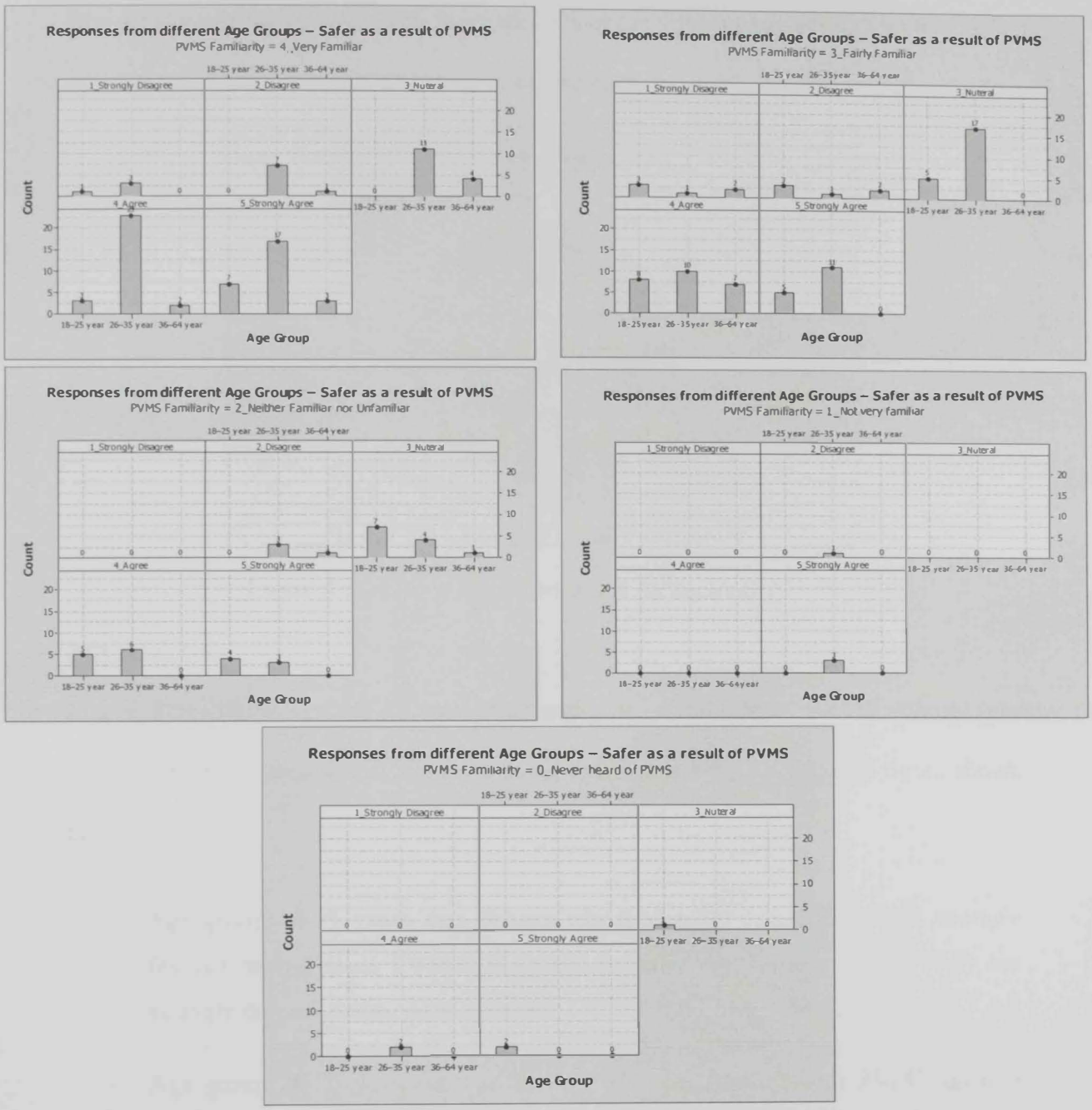


Figure 4.34: Driver's responses on Roadways are safer as a result of PVMS, Age group vs Familiarity of PVMS

About the wider use of PVMS on the road 73% of the drivers were in favor while 7.5% of the respondents disagreed, as shown in Figure 4.35.

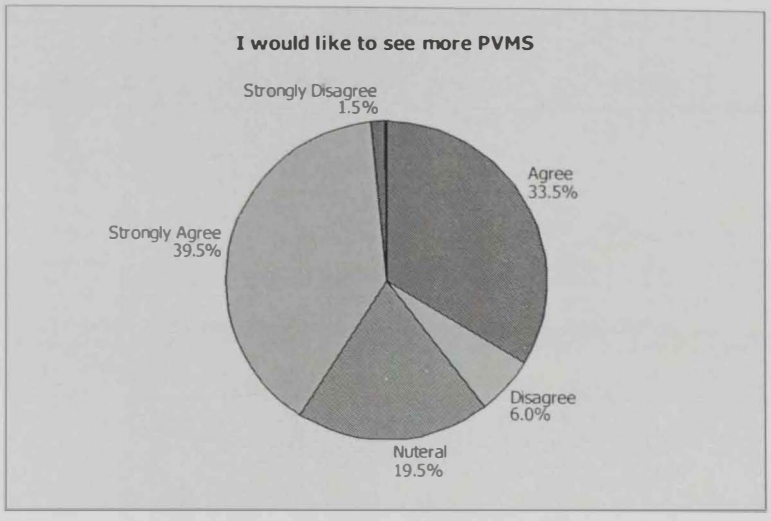


Figure 4.35: Driver responses about seeing more PVMS

Age Analysis

Figure 4.36 illustrates the drivers' responses on seeing more PVMS taking into consideration the variables of age groups and familiarity with PVMS. The figure shows that:

- Age group 18-25 years, two drivers who had never heard of PVMS strongly favored seeing more PVMS. Most drivers who are familiar with PVMS are strongly favored seeing more PVMS.
- Age group 26-35 year, most of drivers who are familiar with PVMS favored wider use of PVMS. Two drivers who are not familiar with PVMS also agreed with wider use of PVMS.
- Age group 36-65 year, Drivers who are familiar with PVMS again favored more of PVMS.

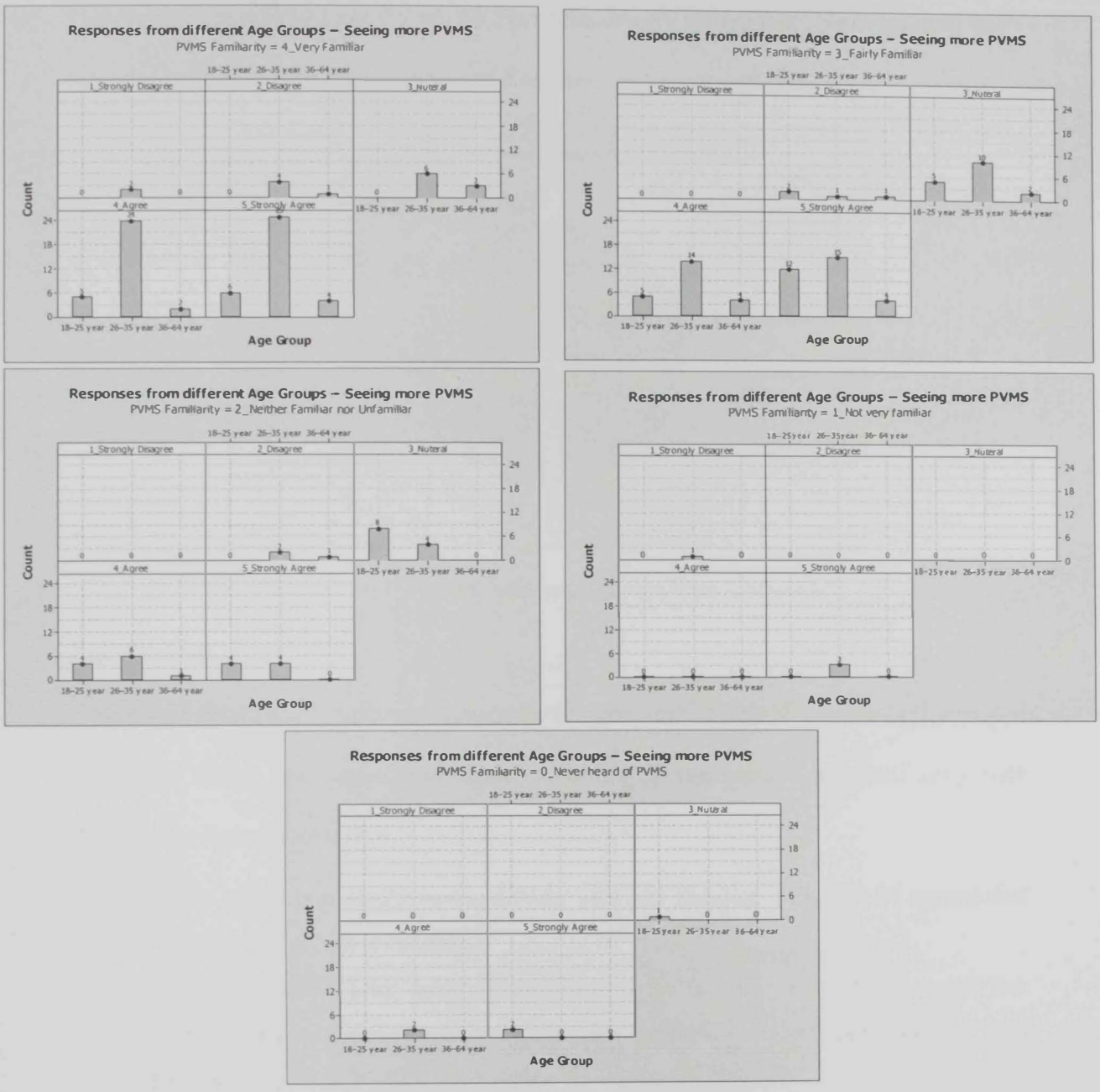


Figure 4.36: Driver responses about seeing more PVMS, Age group vs Familiarity of PVMS

Concerning the reliability of PVMS 66.5% of the drivers agreed that its information was reliable while 10.5% of the respondents disagreed, as shown in Figure 4.37.

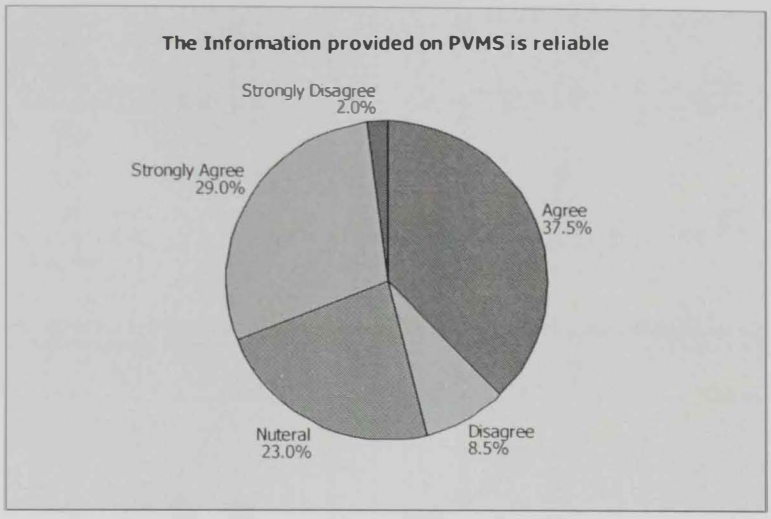


Figure 4.37: PVMS Information provided is reliable

Age Analysis

Figure 4.38 illustrates the drivers' responses on whether the PVMS information provided is reliable taking into consideration the variables of age groups and familiarity with PVMS. The figure shows that:

- In the age group 18-25 years, drivers who are familiar with PVMS agreed that PVMS information is reliable.
- Age group 26-35 year, most of drivers who are familiar with PVMS stated that PVMS information is reliable. Only two drivers, who are not familiar with PVMS, stated that PVMS information provided is reliable.
- Age group 36-65 year, drivers who are familiar with PVMS agreed that PVMS information provided is reliable.

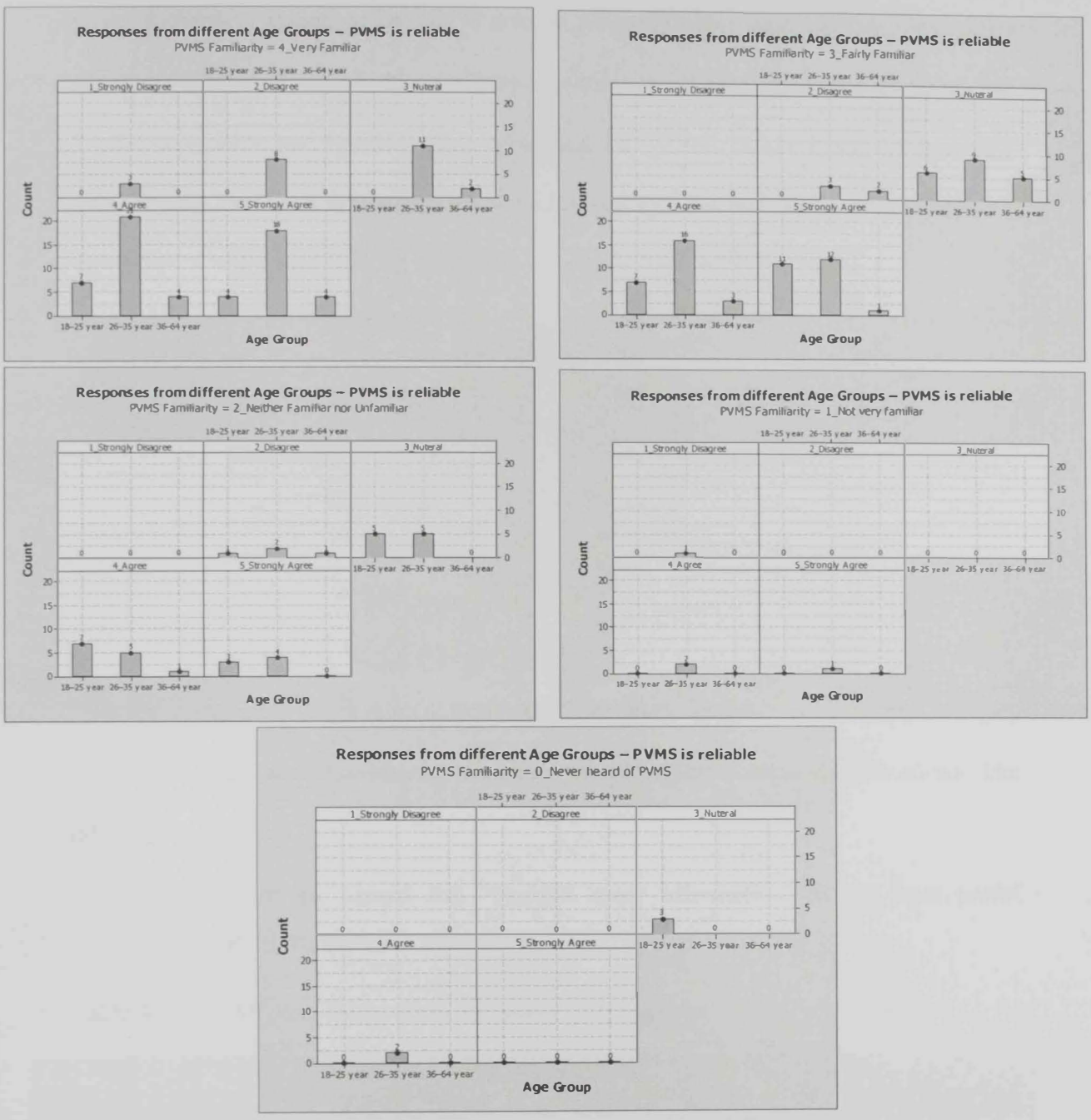


Figure 4.38: Driver responses about PVMS Information is reliable, Age group vs Familiarity of PVMS

On the usefulness of the PVMS message on certain subjects, as shown in Figure 4.39; the highest rate of responses (14.4%) indicated that accidents information got most of the

driver's attention among while 14.1% favored warnings about road hazards. Emergency situations accounted for 14.0% of responses while road works were favored by 13.2%. Traffic congestion and weather information had 12.7% and 12.5% support respectively while special event and time of the day were favored by 8.6% and 10.4% respectively.

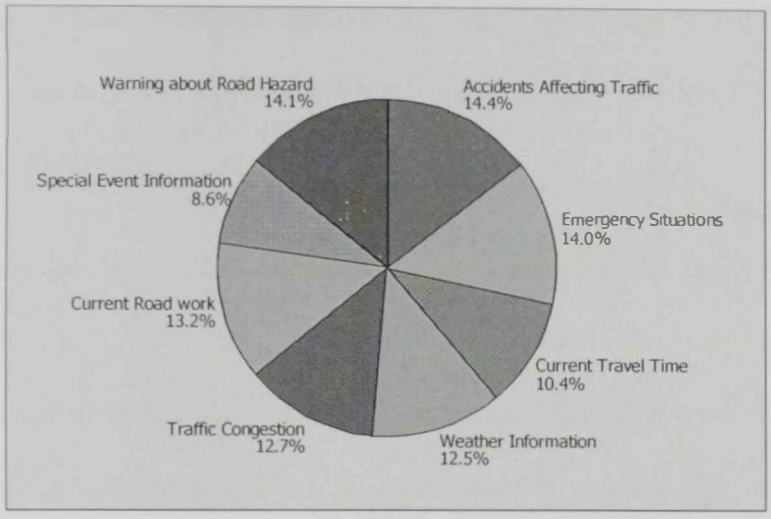


Figure 4.39: PVMS Usefulness Areas

Table 4.18 illustrates the drivers' responses on PVMS usefulness classifications. The table shows that:

- All age groups agreed that "Special event information" is the least useful information compared to other areas.

Table 4.18: PVMS usefulness areas according to age groups

Age Group	PVMS Usefulness Areas							
	Most Usefulness							Less Usefulness
18-25 Years	Accidents Affecting Traffic 14.3%	Emergency Situations 13.7%	Warning about Road Hazard 13.6%	Weather Information 13.2%	Current Road Work 13.0%	Traffic Congestion 12.7%	Current Travel Time 10.9%	Special Event Information 8.6%
26-35 Years	Warning about Road Hazard 14.3%	Accidents Affecting Traffic 14.1%	Emergency Situations 14.0%	Current Road Work 13.4%	Traffic Congestion 12.8%	Weather Information 12.2%	Current Travel Time 10.3%	Special Event Information 8.7%
36-65 Years	Accidents Affecting Traffic 16.2%	Emergency Situations 14.6%	Warning about Road Hazard 13.9%	Weather Information 12.7%	Current Road Work 12.6%	Traffic Congestion 12.3%	Current Travel Time 10.0%	Special Event Information 7.6%

4.5.8 Driver Surveys – Write-in Comments

The final write-in question called for general comments and suggestions. Many respondents offered praise for the study; however, respondents also identified areas for improvement. The most popular comment, with 11 occurrences, was about the PVMS sign appearance. These comments indicate that the PVMS sign is not clear, the sign should appear in a different color, the PVMS sign is small and the PVMS should be located in the road median.

Other comments on the PVMS messages were mainly about; updating the PVMS messages frequently, PVMS messages can be used to show the roadways speed limit that changed recently, PVMS messages shall cover messages related to truck vehicles such as routes, speed limit, and shows allowable time for drive and wildlife crossing in rural areas.

Increasing PVMS driver awareness by campaigns and PVMS being part of the driving license training sessions were also suggested as ways to increase the driver's awareness of PVMS.

Overall, the drivers' response to the PVMS were positive with many suggestions on the current operation of the PVMS, mainly on updating PVMS messages, messages shall be changed frequently, PVMS messages shall cover the benefit areas mentioned in the survey and more care shall be taken with PVMS as a communication tool with the roadways users in order to increase the convenience on PVMS.

4.5 Worker Satisfaction Survey

The worker surveys were conducted to assess workers' opinion on PVMS performance and the effectiveness of the PVMS. The survey analysis is summarized as follows:

4.6.1 Worker's Characteristics

The characteristics of the respondents in terms of their gender, age, education level and license validity duration are shown in Figure 4.40.

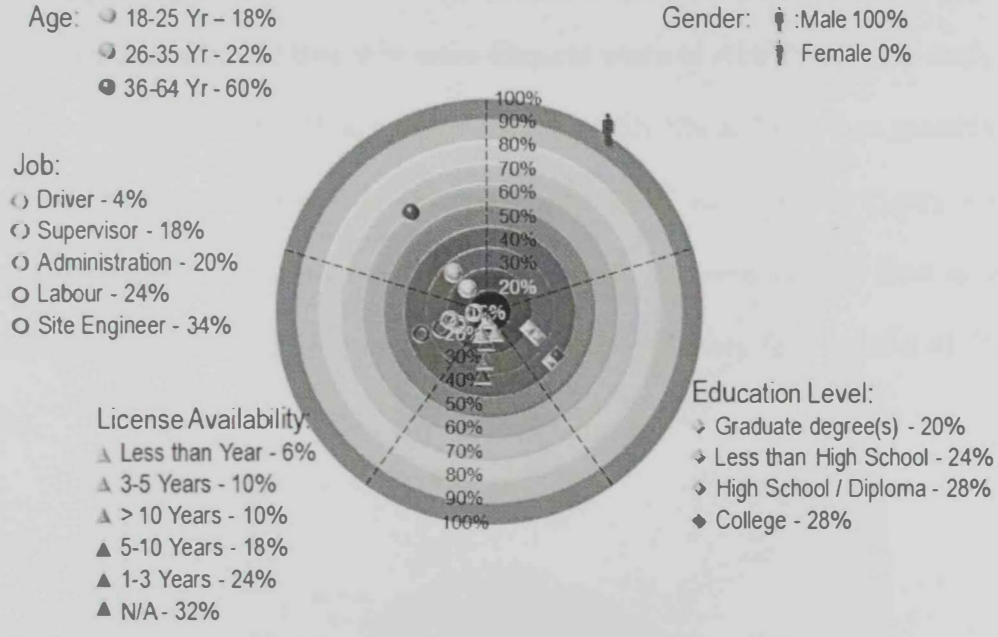


Figure 4.40: Worker Characteristics of the Surveyed Respondents

The worker's characteristics were firstly analysed to make better assumptions and better understand the statistical results that the data would yield. In terms of gender distribution, male and female represented 100% and 0% respectively. In terms of age distribution, 60% were between 26-35 years of age, 18% between 18-25 years of age while 22% represented those over 36 years of age. The education level distribution indicated that those with high school / diploma constituted 28%, college 28%, graduate degree 20% and

without high school certificate 24%. The validity of license duration yielded the following; 10% with more than 10 years, 18% with 5-10years, 10% 3-5years, 24% with 1-3 years and finally 6% with less than a year. It should be noted that 32% were workers had no driving licenses. In terms of job categories, 34% comprised site engineers, 20% were administrative, drivers and laborers constituted 4% and 24% respectively while supervisors comprised 18%.

4.6.2 Frequency on Abu Dhabi Roads and awareness of PVMS

Most respondents indicated that they were frequent users of Abu Dhabi case study roads with daily users comprising 48%, weekly 10%, monthly 8% and less than monthly 34%, as shown in Figure 4.41. On their awareness of PVMS, as shown in Figure 4.42, the results indicated that 2.5% have never heard of PVMS, 2% were not very familiar with it, 17% indicated neutrality. 37.5% indicated that they were fairly familiar and 41.5% very familiar.

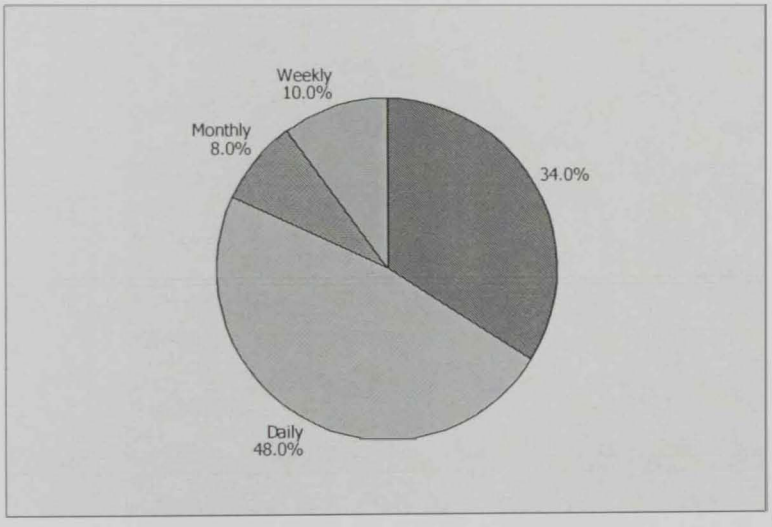


Figure 4.41: Frequency of driving on Abu Dhabi Roads

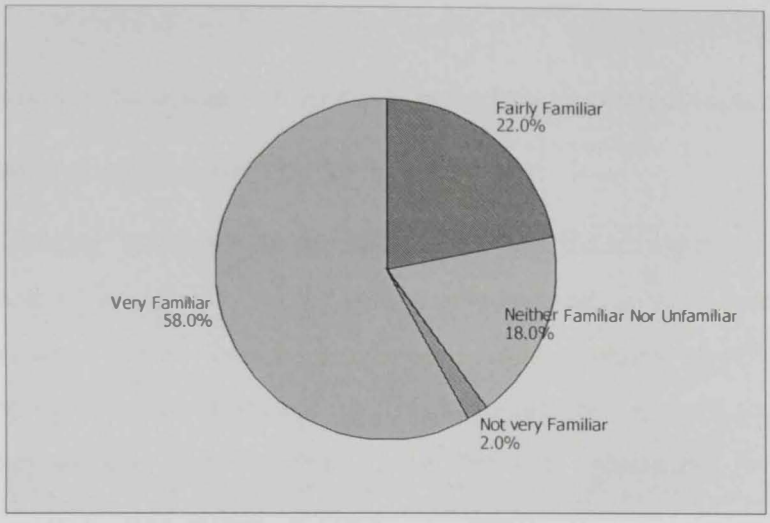


Figure 4.42: Worker's Awareness of PVMS

4.6.3 Equipment choice for Traffic Safety management at the work zone

On the suitability of the best traffic equipment for traffic safety management at the work zone, the results, as shown in Figure 4.43, indicated that workers were in favour of PVMS with 78% approval, followed by fixed signs at 20% and only 2% for flagging.

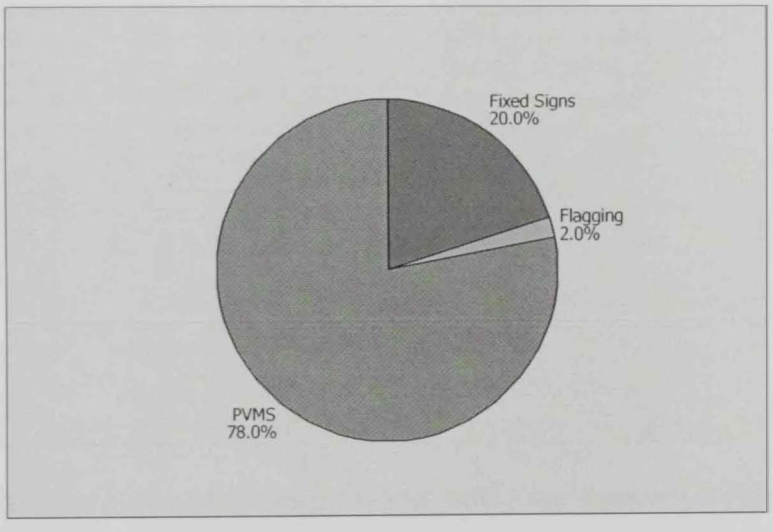


Figure 4.43: The best equipment used for traffic safety management at Work Zone

Job Analysis

Figure 4.44 illustrates the workers' responses on the best equipment to be used for traffic safety management at work zones. The figure shows that:

- Administration workers' stated that PVMS and fixed signs are the preferred equipment to be used in traffic safety management at work zones. All of the administration workers had driving licenses which explains why PVMS is favored as the best equipment to be used for traffic management at work zones.
- All other workers stated PVMS to be the best equipment for traffic safety management at work zones.
- Only one site engineer stated that flagging is the best equipment used for traffic safety management at work zone.

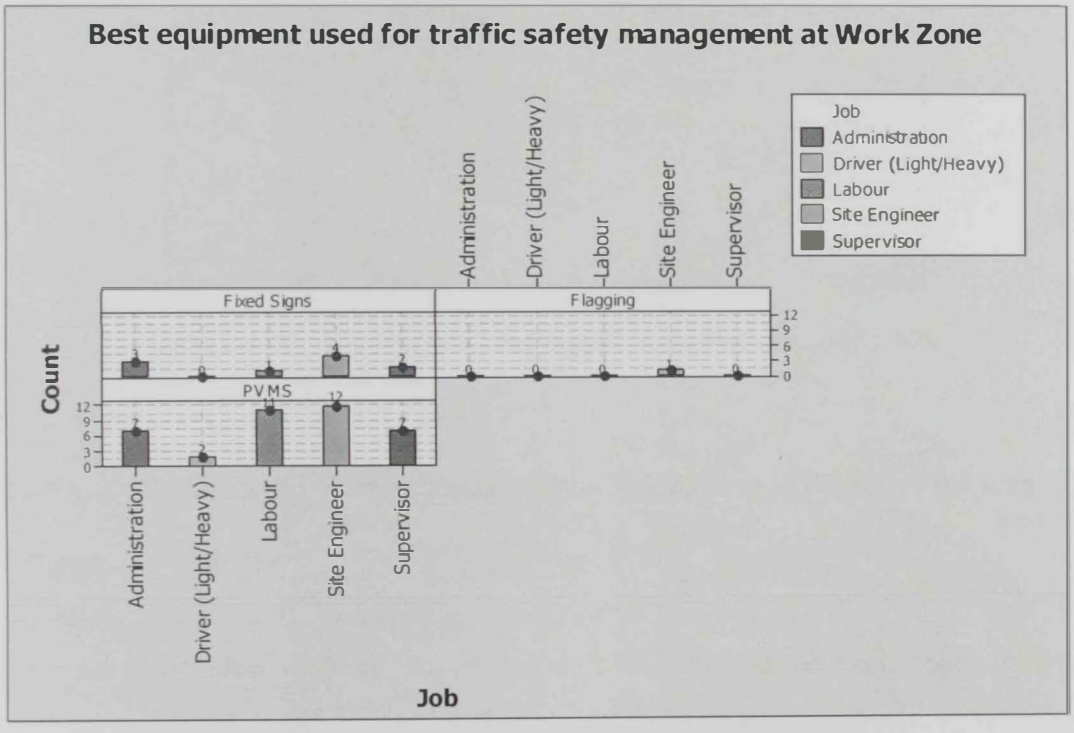


Figure 4.44: The best equipment used for traffic safety management at Work Zone based on workers' jobs

4.6.4 The Helpfulness of the PVMS at the Work Zone

In their replies 68% of the respondents indicated that PVMS is extremely helpful at work zones, 24% of the responses considered PVMS to be very helpful at the work zone, and 6% of workers stated that PVMS is somewhat helpful at the work zone. Only 2% of the workers indicated that PVMS is just slightly helpful at the work zone, as shown in Figure 4.45.

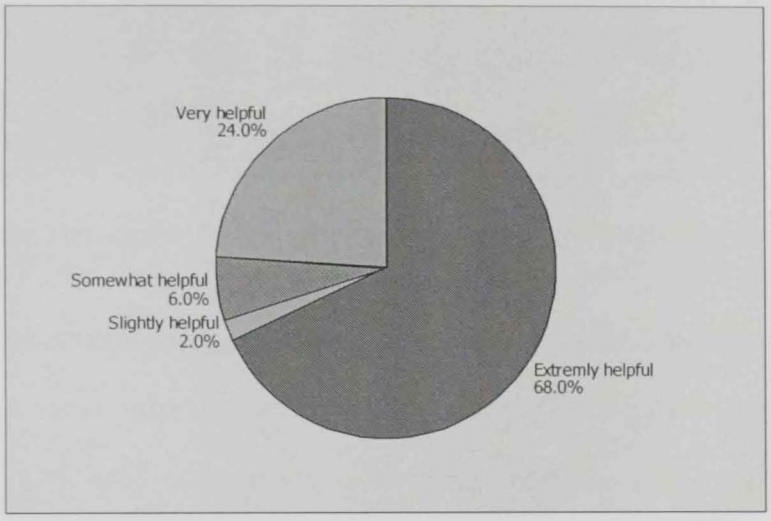


Figure 4.45: The workers' responses on helpfulness of PVMS

Job Analysis

Figure 4.46 illustrates the workers' responses on helpfulness of PVMS vs workers' jobs. The figure shows that:

- Administration workers' stated that PVMS is helpful at work zones, only one administration worker stated it is only slightly helpful.
- All drivers (2 numbers) agreed that PVMS is extremely helpful.
- Site engineers, laborers and supervisors agreed that PVMS is helpful at work zones.

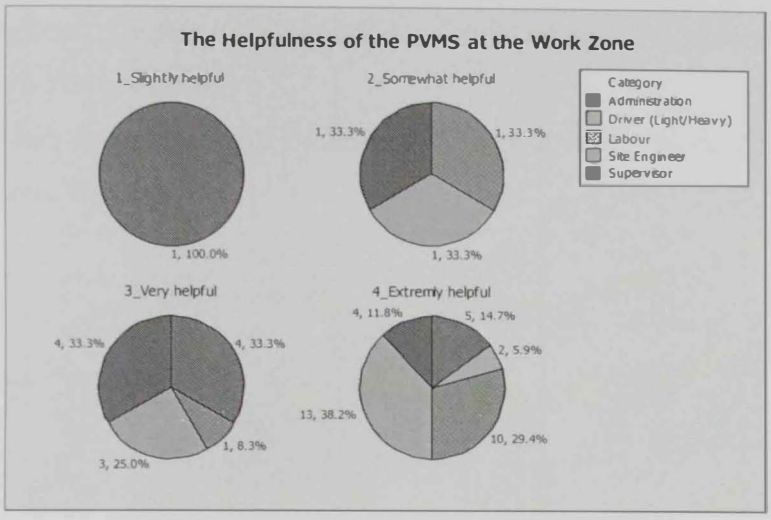


Figure 4.46: The workers' responses on helpfulness of PVMS vs workers' Jobs

4.6.5 PVMS Message Information to be displayed and Message Subject

The survey gave varied responses to the type of the information that should be displayed at work zones with 36% of respondents favoring Work Zone Workers Warning (Be Aware – Workers) and 28% choosing Speed (Speed Limit: ## km/hr). Work Zone (Work Zone Ahead) was favored by 20% of respondents while Information (Expected Delay) and 10% Advisory (Use Alternative Roads) garnered only 10% and 6% support respectively. On the message subject, 33.8% favored Lane Closure messages while 26.8% were for Work Zone Ahead and 12.7% favored Use Alternative Roads, as shown in Figure 4.47.

Job Analysis

- Administration workers' favored PVMS messages displayed about Work Zone, Work Zone Workers, Speed and Information.
- Driver workers' favored PVMS messages displaying information about about Speed.

- Laborers favored PVMS displays about Speed, Work Zone Workers and Work Zone.
- Site Engineers favored PVMS messages displayed about Work Zone, Information and Work Zone Workers.
- Supervisors favored PVMS message's displayed about Work Zone, Speed and Work Zone Workers.

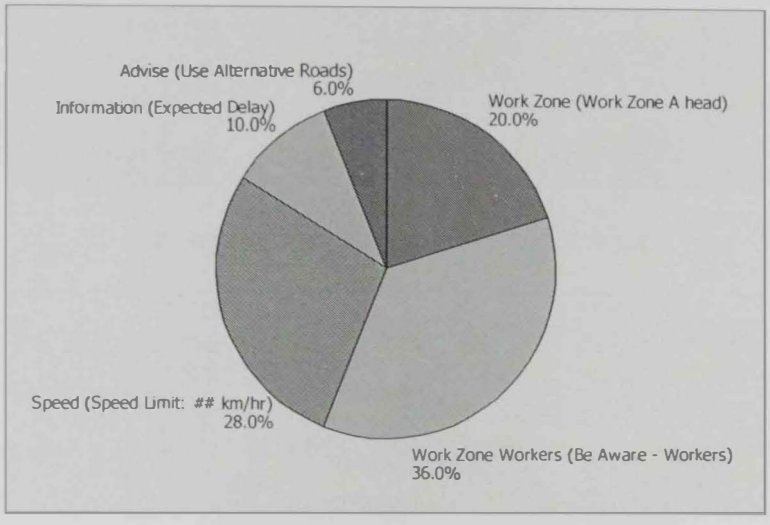


Figure 4.47: PVMS Message Information Importance

4.6.6 Accuracy of the PVMS Message and Reading PVMS Messages

With regard to PVMS message accuracy, as shown in Figure 4.48, 66% of the workers indicated that PVMS messages are accurate, while 10% stated that PVMS messages are not accurate and 24% of workers stated that they couldn't read the PVMS messages. On the other hand, 56% of the workers indicated that they always or most of the time read the messages, 20% sometimes and 24% rarely or never read the messages, as shown in Figure 4.49.

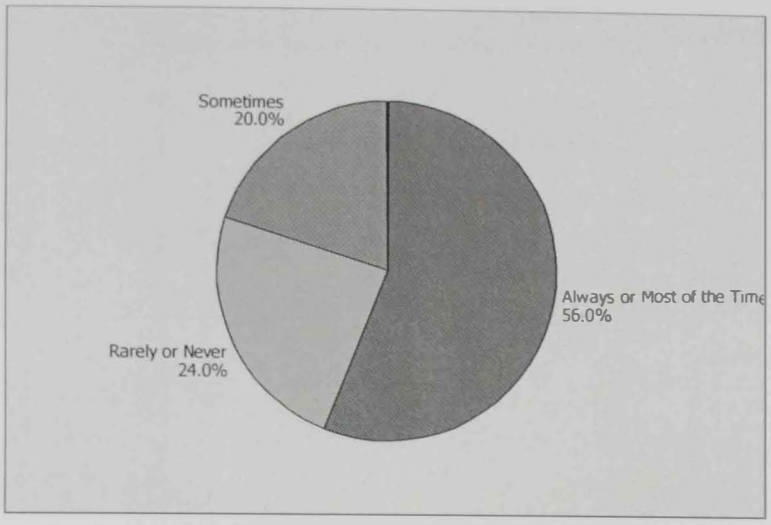


Figure 4.48: Accuracy of PVMS Message

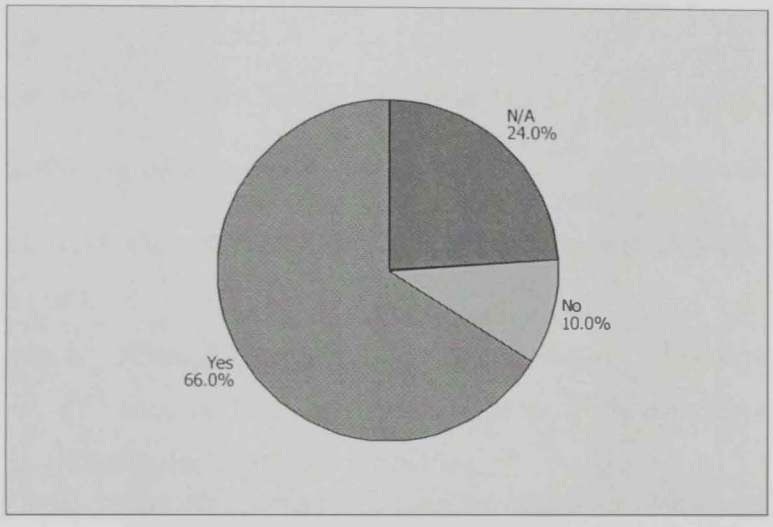


Figure 4.49: Reading PVMS Message

4.6.7 Evaluation of PVMS

In evaluating the effectiveness of the PVMS, within work zones, as shown in Figure 4.50; 94% of the respondents strongly agreed or agreed that the implementation of PVMS had been positive while 2% of the workers indicated that they disagreed that implementation of PVMS had been positive.

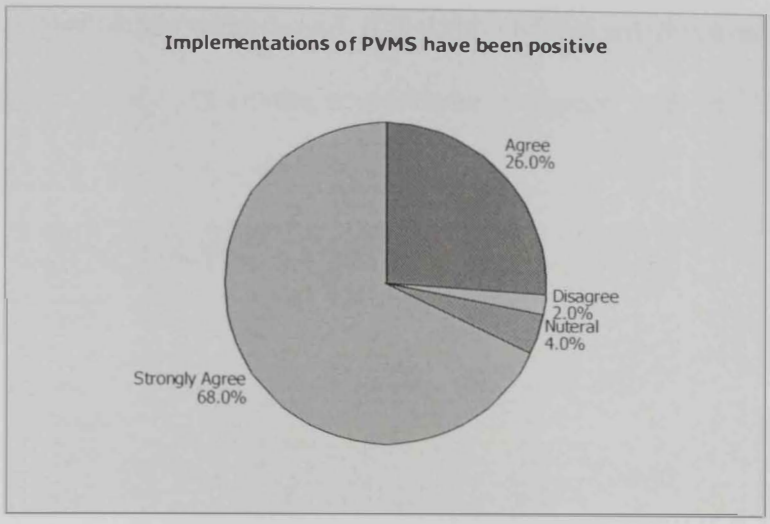


Figure 4.50: PVMS Message Implementation is Positive

Job Analysis

Figure 4.51 illustrates the workers' responses about "PVMS Implementation is positive" vs workers' jobs. The figure shows that:

- Of the administration workers, only one worker disagree that implementation of PVMS is positive.
- Driver workers' strongly agreed that implementation of PVMS is positive.
- A majority of Laborers, Site Engineers and Supervisor agreed on the statement that the implementation of PVMS is positive.

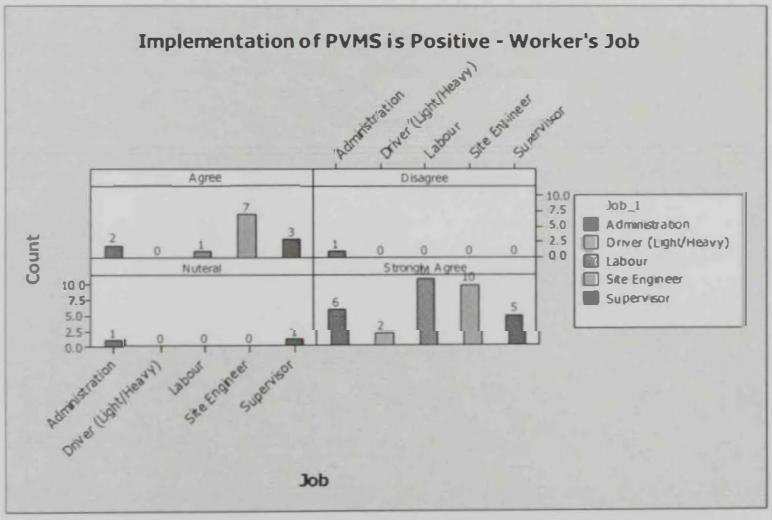


Figure 4.51: PVMS Message Implementation is Positive vs workers' Jobs

As shown in Figure 4.52, when asked if PVMS had helped them at work. 84% of respondents agreed while 2% of the respondents disagreed with 16% not having an opinion.

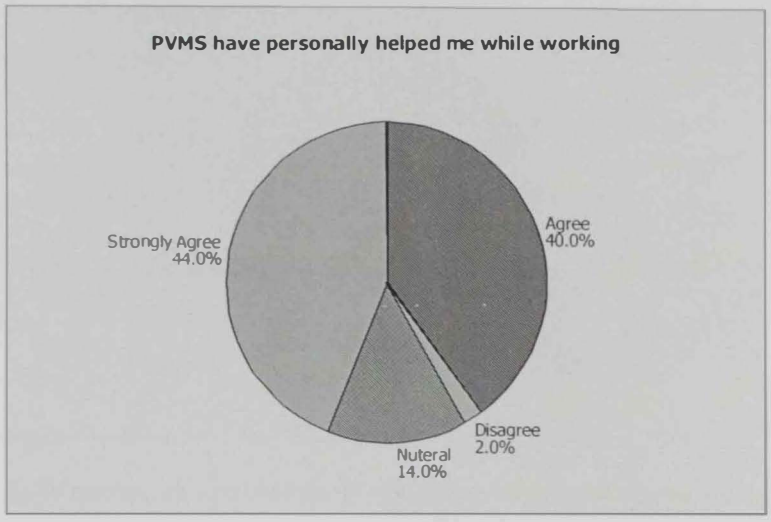


Figure 4.52: PVMS Message helped workers while working

Job Analysis

Figure 4.53 illustrates the workers' responses about "PVMS helped workers while working" vs workers' jobs. The figure shows that:

- Majority of workers agreed that PVMS helped them while working.

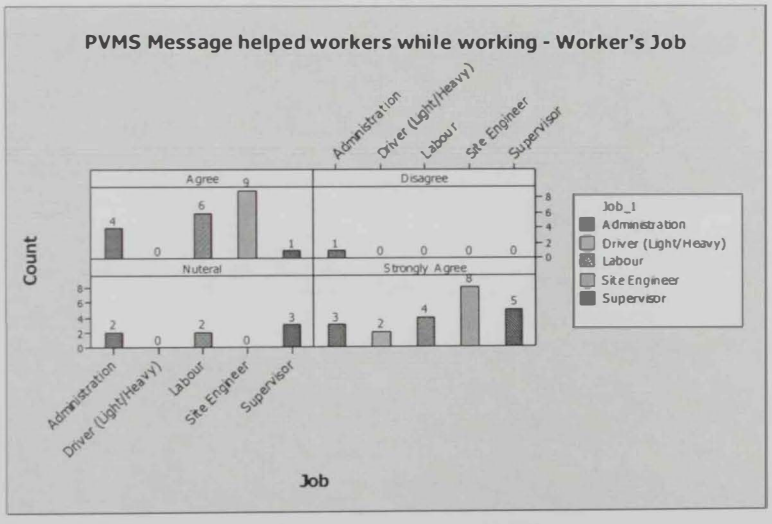


Figure 4.53: PVMS Message helped workers while working vs workers' Jobs

88% of the workers' agreed that work zones are safer as a result of PVMS while 4% of the respondents disagreed, as shown in Figure 4.54.

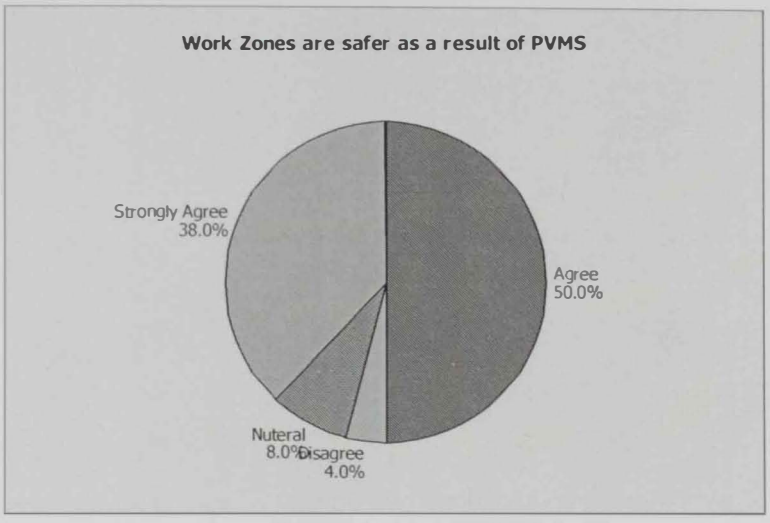


Figure 4.54: Workers' responses on Work zones area safer as a result of PVMS

Job Analysis

Figure 4.55 illustrates the workers' responses about "Work zones are safer as a result of PVMS" vs workers' jobs. The figure shows that majority of workers agreed on "Work zones are safer as a result of PVMS". Only two workers disagree that Work zones are safer as a result of PVMS.

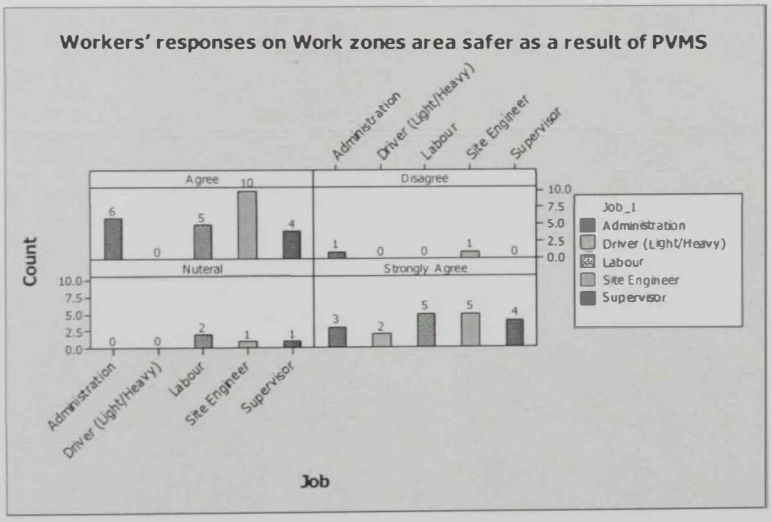


Figure 4.55: Work zones area safer as a result of PVMS vs workers' job

When asked if they wanted to see more PVMS deployed at work zones 88% of the workers agreed while 2% of the respondents disagreed, as shown in Figure 4.56.

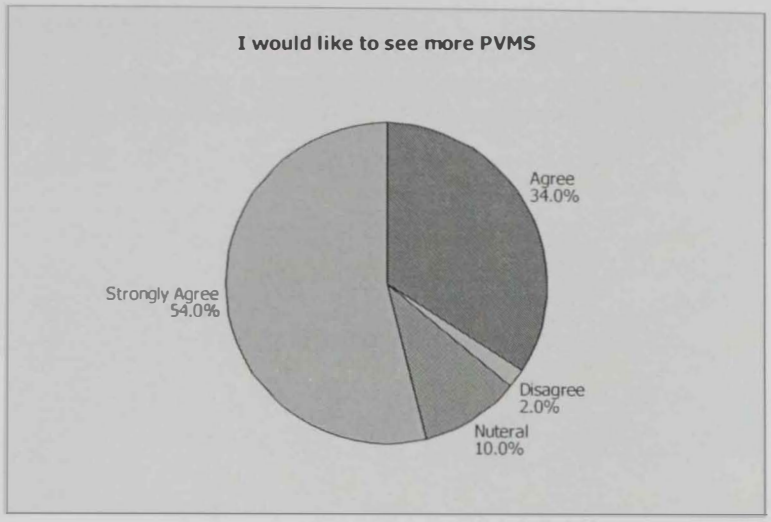


Figure 4.56: Workers' responses about seeing more PVMS

Job Analysis

Figure 4.57 illustrates the workers' responses about "seeing more PVMS at Work zones" vs workers' jobs. The figure shows that the majority of workers agreed on "seeing more PVMS". Only one Worker (Administration) disagreed about seeing more PVMS at Work zones.

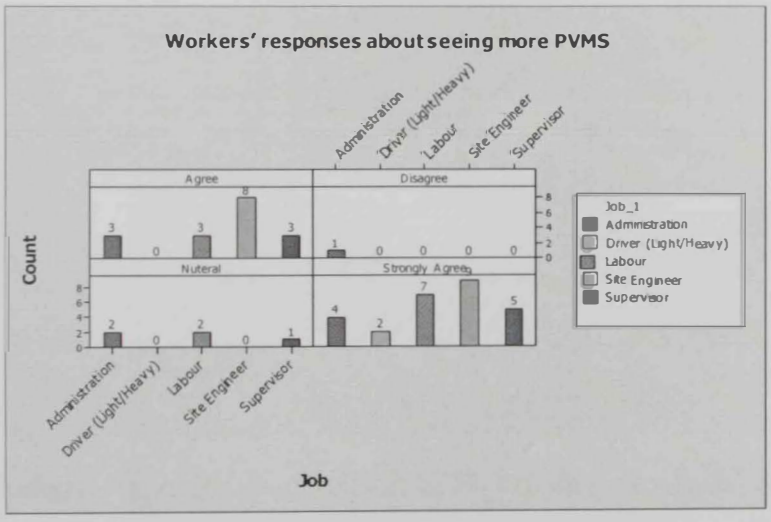


Figure 4.57: Workers' responses about seeing more PVMS vs workers' job

Finally, 50% of the drivers agreed on the reliability of the PVMS messages while 4% of the respondents disagreed, as shown in Figure 4.58. On other hand, workers' who can't read the PVMS messages were assigned as N/A.

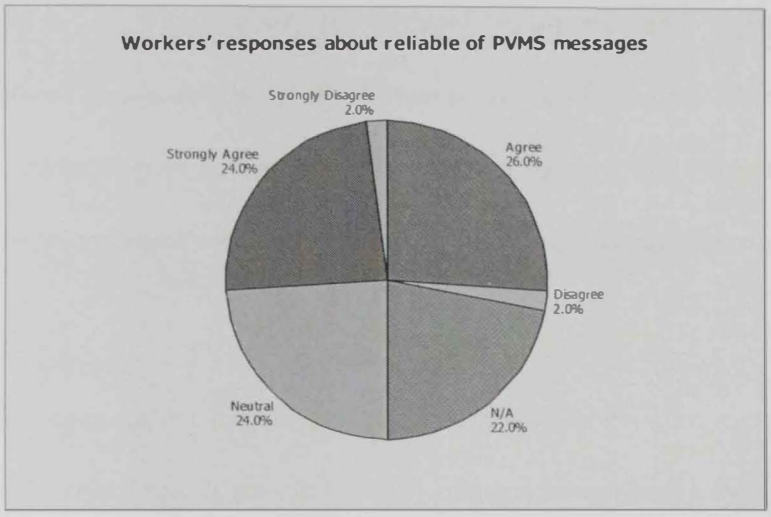


Figure 4.58: Workers' responses about reliable of PVMS messages

Job Analysis

Figure 4.59 illustrates the workers' responses about "reliability of PVMS messages" vs workers' jobs. The figure shows that majority of workers agreed on that.

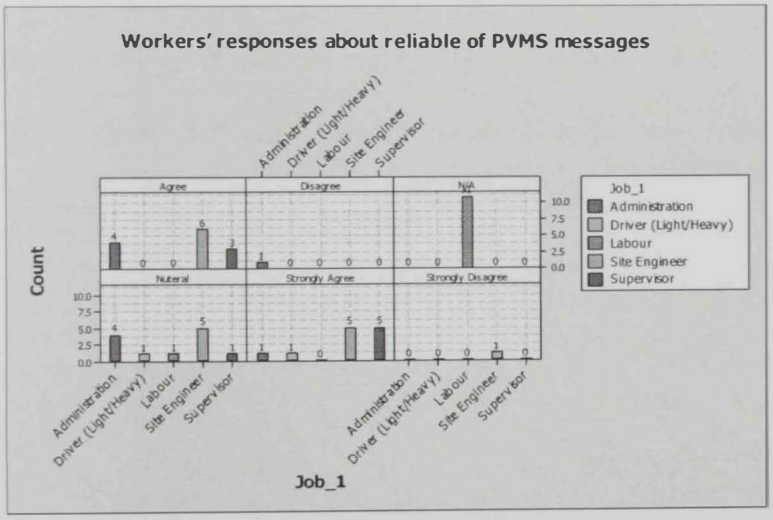


Figure 4.59: Workers' responses about reliable of PVMS messages based on Job analysis

4.6.8 Worker Survey – Write-in Comments

The final write-in question called for general comments and suggestions. Many respondents offered praise for the study; however, respondents also identified areas for improvement. The most popular comment, with 4 occurrences, was about the PVMS sign appearance. These comments indicate that the PVMS sign is not clear and effective at night only.

Other comments were on the implementation of the PVMS concerning; not common in most of the work zone areas, it should be implemented immediately over all work zones within Abu Dhabi, should be well maintained through the whole construction period and not cleared away until work zone is cleared. PVMS should be routinely used at the work zones in order to increase public awareness.

Overall, the workers responses to the PVMS were positive and they feel comfortable and safe while working in the work zone at night only if PVMS is installed. Workers stated that current PVMS operation is not efficient and needs to be developed more and well maintained.

CHAPTER 5: DISCUSSION

5.1 Introduction

The purpose of this study was to evaluate the effectiveness in improving safety for motorists and workers at construction zones in Abu Dhabi. In line with the objective, the discussion is organized to understand the impact of PVMS on vehicle speeds, crash trends in the emirate of Abu Dhabi and the selected roads in this study, drivers and workers satisfaction surveys feedback on PVMS deployment.

5.2 Discussion

The analysis was performed to evaluate the impact of the PVMS through examining the significance and differences of speed means for the cases before and after installing PVMS, The data was used to provide a trends analysis for crashes on the selected roads and to investigate the driver's survey worker's survey feedback. The following sections discuss the analysis results.

5.2.1 Speeds

An analysis on the effectiveness of PVMS on reducing speeds yielded varied results.

E11 Road

On the E11 Road (work zone), the analysis shows that the average speed is about 25km/hr more than the speed limit. The change in average speed between the after PVMS and before PVMS cases is not significant with difference of about ±1%. At the 95 percent confidence level the before and after 85th percentile speeds were not significantly different. Overall, the results show that about 90% of vehicles are not complying with the

speed limit. A reduction of only 0.81% was observed in the proportion of vehicles travelling at speeds of 140km/hr to more than 160km/hr.

The 2 sample t-test performed indicated that there is a statistically significant difference in mean speed (p-value < 0.005) but the negative t-value indicated that mean speed for the before PVMS case is less than the speed mean for the after PVMS case that is due to the increase in Class 2 vehicles that have higher speeds for the after case. The 2 sample t-test of upstream and downstream mean speeds with the before PVMS mean speed is not applicable due to the difference in speed limit at these locations. The 1 sample t-test performed indicated that there is no statistical significance difference between the before and after PVMS speed means with the speed limit at the work zone. The positive t-values indicates that mean speed for the before and after PVMS cases are greater than the speed limit. The t-test results for the upstream and downstream mean speed with the speed limit show that there is a statistically significant difference (p-values < 0.005), but negative t-values indicate that the upstream and downstream mean speed are less than the speed limit due to the nature of these locations that are nearby a places where drivers accelerating/decelerating.

For Class 1 vehicles on the same road section, the analysis showed that there was a change in speeds, while Class 2 vehicles, the analysis showed that the mean speed increased by about 3% after implementation of the PVMS. For Class 3 vehicles, the results indicate that the mean speed increased after the PVMS installation. Further, the proportions of speeding vehicles increased after installing PVMS. In conclusion, the analysis showed no statistical significance with regard to a reduction in work zone speeds

as a result of the deployment of the PVMS. This may have been attributed to the variations in posted speed limit over a short span where they gradually decreased from 140km/hr to 120km/hr, then 120km/hr to 100 km/hr, then 100km/hr to 80km/hr.

E10 Road

On the E10 Road (Al Raha Beach section), for all vehicles the analysis showed that the average speed was about 15km/hr less than the speed limit. There was a minor reduction in average speed by about 1% after installing the PVMS. At the 95 percent confidence level the before and after 85^{th} percentile speeds were not significantly different at about 1km/hr. The overall figures show that about 28% of the vehicles are not complying with the speed limit. The change in proportions of high speeds is limited to speeds of 140km/hr to more than 160km/hr with a reduction of 2.37%.

The 2 sample t-test performed indicated that there was no statistically significant difference in mean speed (p-value > 0.005) after installing the PVMS at the upstream and downstream of the PVMS, that was due to the existing condition at these locations where vehicles accelerating/decelerating. Positive t-value indicated that the mean speed for the Before PVMS case is greater than the speed mean for the After PVMS case at PVMS location, upstream location and at the downstream location. The 1 sample t-test performed for before PVMS and after PVMS, indicated that there is a statistically significant difference where the p-value is less than 0.005. The negative t-values indicated that the mean speed was less than speed limit.

For Class 1 vehicles on the same road section, the analysis showed that most of the results are identical to those for all vehicles as the majority of vehicles (about 73%) on

this section were Class 1 light vehicles. For Class 2 the analysis showed that the mean speed did not decrease significantly (about 1%). after implementation of PVMS. The decrease in the proportions of speeding vehicles was about 2.38% in the speed band more than 140 km/hr. For Class 3 vehicles, the results indicated that the mean speed decreased after PVMS installation (about 1% to 4%) and the proportions of speeding vehicles decreased after installing PVMS with about 2.66% for speeds more than 110km/hr.

Eastern Ring Road

On the Eastern Ring road, for all vehicles the analysis showed that the average speed was about 26km/hr less than the speed limit. There was a minor reduction in average speed by about 1%-2% after installing PVMS. At the 95 percent confidence level the before and after 85^{th} percentile speeds were not significantly different (1km/hr). Overall, about 2% of the vehicles were not complying with the speed limit. The change in proportions of high speeds was limited to speeds more than 90km/hr where a reduction of 4.05% was observed. There was a slight increase in average speeds at low speeds.

The 2 sample t-test performed indicated that there was no statistically significant difference between the speed means of before PVMS and after PVMS since the p-value is > 0.005. Positive t-values indicated that the mean speed for the before PVMS case is greater than the speed means for the after PVMS case. The 2-sample t-test performed for the upstream after PVMS mean speed compared with the before PVMS indicated that there was a statistically significant difference since the p-value is < 0.005. Negative t-values indicated that the mean speed for the before PVMS case was less than the mean speed for the after PVMS case. For the case of downstream the after PVMS compared

with the before PVMS, the t-value and p-values indicated that there was no statistically significant difference in mean speed for the before case. The 1 sample t-test performed for before PVMS and after PVMS, upstream and downstream indicated that there was a statistically significant difference where p-value is less than 0.005. The negative t-values indicated that the mean speed was less than the speed limit.

For Class 1 the analysis showed that the results are typical of all vehicles due to the fact that Class 1 vehicles formed the majority of the traffic. (About 87% of all vehicles are light vehicle Class1). For Class 2 vehicles, the analysis showed that the mean speed was not decreased significantly reducing by only about 1%-2% after implementation of PVMS. The decrease in the proportions of high speed traffic was about 3% for speeds more than 90 km/hr. For Class 3, the results indicated that the means speed decreased after the installation of PVMS (about 1% to 4%). Also the proportions of speeding vehicles decreased after installing PVMS, falling by about 6.21% for speeds more than 90 km/hr.

5.2.2 Accident Records

In this study, the PVMS were installed for short time during speed survey. Therefore, the crash trend analysis can't measure the impact of PVMS where crash evaluation after the PVMS installation will require several years of crash data in order to obtain a statistically significant sample.

However, it is important to realize that there are many influences on vehicle crashes making it difficult to determine with absolute certainty the causes and effects of crashes.

5.2.3 Satisfaction

The results of the driver survey indicate that a majority of surveyed drivers were aware of PVMS and considered the PVMS messages as accurate. 54 percent of the surveyed drivers interpreted that they read the PVMS messages always and more than a half of surveyed drivers considered PVMS visually appealing, easy to read and appreciated the messages being provided in two languages (Arabic and English). On the other hand, the motorists reported that the difficulties in reading the PVMS messages were mainly obstruction of the signs by traffic. When asked what type of messages should be displayed, more than 29 percent of surveyed drivers indicated that accident and/or road hazard warning messages are the most important to be displayed on PVMS. More than 60 percent of surveyed drivers responded positively when they were asked to evaluate the effectiveness of the PVMS. Overall, more than 60 percent of the surveyed drivers recommended the implementation of the PVMS for alerting drivers to incidents affecting traffic flow including road hazards, emergency situations, current road works, traffic congestion, and weather information.

The drivers' response to the PVMS were positive with many comments on the current operation of the PVMS mainly about updating the PVMS messages, messages which should be changed frequently, PVMS messages should cover more areas and more care shall be applied to PVMS as a communication tool with the roadways users in order to increase the usefulness on PVMS.

The work zone survey indicated that surveyed workers were aware of PVMS and considered PVMS as the best tool used for traffic safety at work zones. More than a half of surveyed workers considered that PVMS is extremely helpful at the work zones while

more than 35 percent of surveyed workers indicated that the PVMS message "Be Aware – Workers" is the most important to be displayed on the PVMS. Of the surveyed workers, 56 percent interpreted that they read the PVMS messages always and 66% of the surveyed workers agreed with the accuracy of the PVMS messages signs. More than 50 percent of surveyed workers responded positively when they were asked to evaluate the effectiveness of the PVMS and indicated that PVMS enhanced work zones safety during night periods.

Overall, the worker's responses to the PVMS were positive and they feel comfortable and safe while working in the work zone during night time only if PVMS is installed. Workers stated that current PVMS operation is not efficient and needs to be developed more and well maintained to be a common tool used at work zones.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

The main purpose of this study was to evaluate the effectiveness of PVMS by comparing the speeding behavior of drivers before and after the implementation of PVMS.

Moreover, drivers' and road construction workers' opinion surveys were conducted to evaluate the user perspective of PVMS performances.

The study findings are consistent with the findings of other similar studies conducted in different countries. The conclusions from this study can be summarized as follows:

i. PVMSs were found to be ineffective in reducing speeds. Mean and 85th percentile speed differences before and after the deployment of PVMS were not statistically significant in most scenarios. Moreover, in some time periods speeds observed in the after scenario were more than before scenario.

ii. The mean and 85th percentile speeds in the work zone study location are well above posted speeds as well as allowable speeds. There are more than 90% of vehicles exceeding the speed limit at work zone study locations.

iii. In urban and rural areas, PVMS has only a minor impact in reducing driver's speeds but was shown to be not statistically significant. However, at the work zone, PVMS had no impact in reducing driver's speeds.

iv. Newly deployed PVMS confuse drivers especially when the posted speed limits are reduced over a short span length.

v. The proportion of vehicles speeding excessively (i.e. vehicles traveling over the posted speed limit) was slightly decreased by the use of PVMS.

vi. Driver surveys indicate that most drivers are positive towards VMS information.

vii. Road users considered PVMS can be an effective tool in alerting drivers about irregular traffic conditions or any incidents.

viii. Messages conveyed through PVMS are easy to understand by road users. However, it can be clearer if pictures and symbols are used to aid the illiterate or those not able to read Arabic and English especially at work zones.

ix. Road users want more frequent use of PVMS and more care on the current operation of the PVMS.

x. Road users commenting on the operation of PVMS indicated that many PVMSs are not frequently updated thus not reflecting the current situation of the roadways.

xi. Road Construction Workers consider PVMS as an essential tool for safety and alerting drivers about work zone during night time only.

xii. According to construction workers', maximum speed limit and work zone ahead messages are most important.

xiii. In this study, the PVMS were installed for short time during speed survey. Therefore, the crash trend analysis can't measure the impact of PVMS where

crash evaluation after the PVMS installation will require several years of crash data in order to obtain a statistically significant sample.

xiv. There are many influences on vehicle crashes making it difficult to determine with absolute certainty the causes and effects of crashes.

While the study analysis has found that PVMS are ineffective in managing speeds, some recommendations can be drawn from the study. These include:

i. The deployment of PVMS should be intensified to cover most of Abu Dhabi highways and work-zone areas.

ii. The PVMS messages should be updated regularly and be varied to provide more ways of alerting drivers of various incidents to help avoid major accidents.

iii. The PVMS should be linked to the central traffic control center to enhance real time display of messages in response to prevailing situations.

iv. More research can be carried out to evaluate PVMS using accident analysis, to assess the effectiveness of conveying information related to traffic conditions.

v. It is recommended to conduct more studies of work zones to evaluate the effectiveness of PVMS on work zone accidents.

vi. In conclusion, PVMS is an effective tool if it is operated effectively.

REFERENCES

Aaron B Wilson, Mitsuru Saito (2012). Evaluation of the effectiveness of variable advisory speed system on queue mitigation in work zones. Procedia – social and behavioral scinces 43, page 662-670. Changsha, China.

Abu Dhabi Department of Transport (DoT – 2011). Estimating the Economical Cost of Traffic Crashes in the Emirate of Abu Dhabi, Booz&Co, Abu Dhabi, June 2011.

Abu Dhabi Department of Transport (DoT – 2009). Draft ITS requirement, Abu Dhabi, June 2009.

Ali S. Al-Ghamdi (2005). Experimental evaluation of fog warning system. Accident Analysis and Prevention 39, Page 1065-1072. Published by Elsevier 2007.

Alena Erke, Fridulv Sagberg and Rolf Hagman (2007). Effects of route guidance variable message signs (VMS) on driver behavior. Institute of Transport Economics, Gaustadalleen 21, NO-0349 Oslo, Norway.

Alena Hoye, Michael Sorensen, Rune Elvik, Juned Akhtar, Tor-Olav Nævestad, Truls Vaa (2011). Evaluation of variable message signs in Trondheim. Norwegian Centre Transport Research. Oslo, TOI Report 1153/2011, 263 pages

Amanda Hardy, Scott Lee, & Ahmed Al-Kaisy. (2006). Effectiveness of animal advisory messages on dynamic message signs as a speed reduction tool: case study in Rural Montana. Transportation Research Board 85th Annual Meeting, Washington, DC, USA.

Arash Moradkhani and Othman Puan (2009). Assessment of Impact of Variable Message Signs on Traffic Surveillance in Kuala Lumpur. IEEE, ISI 2009, TX, USA.

Brigitte Cambon de Lavalette, Charles Tijus, Sebastien Poitrenaud, Chritine Leproux (2007). Road Travel Time Information on VMS and Traffic Congestion. IEEE, the 3rd International conference on wireless and mobile communication, France.

Birdsall, M., S. (2008). The Debate over Digital Billboards: Can New Technology Inform Drivers without Distracting Them? ITE Journal (April 2008), Page 22-27.

Cheo Oh, Seung pyo Hong and Jun hyeong Park (2009). Analysis of Driver Behavior in Response to Variable Message Signs (VMS) Using In-vehicle Differential Global Positioning Systems (DGPS) Data, Presented at Transportation Research Board 88 Annual Meeting, January 12, 2009, Washington, D.C.

Chris Lee, Bruce Hellinga and Frank Saccomanno. (2006) Evaluation of variable speed limits to improve traffic safety. Transportation Research Part C, Volume 14, issue 3, p. 213-228.

Cooper, B.R. & Sawyer, Helen E. (2005). Assessment of M25 Automatic Fog-Warning System _ Final Report. Washington D.C., USA: Federal Highway Administration.

Copenhagen Plans Ahead: The Danish Capital is Laying the Foundations of a New Approach to Traffic Management. (2005). ITS International, 11(4), pp 58_59.

Dominic Paulo, Geoff Collins, Cliver Cooper, Raju Patel, and Sherwin Wallace. M25 Speed Harmonisation. In the proceeding of Road Transport Information and Control Conference and the ITS United Kingdom Members' Conference (RTIC 2010) – Better transport through technology, IET, London, UK. 25 -27 May 2010, pp 1 -5

Fang Clara Fang (2008). Portable Intelligent Traffic Management System for Work Zones and Incident Management Systems: Best Practice Review. Conference on Intelligent Transportation Systems, 11th International IEEE. Beijing, China.

Finger, K., Bai, Y., Li, Y., & Firman, U. (2009). Determining Motorists' Response to Signage in Rural Highway Work Zones. Paper presented at the Transportation Research Board 88th Annual Meeting, Washington, DC, USA.

Guan Jizhe, Zheng Changping, Liu Jinkun, Wang Yisheng, Qiao Liang, Ji Yanling (2008). VMS Release of Traffic Guid Information in Beijing Olympics. Journal of Transportation, Volume 8, Issue 6, China.

Health Authority Abu Dhabi (HAAD – 2010). Health Statistics 2010, Abu Dhabi, 2011.

Kevin Heaslip, John Collura, Michael Knodler (2009). Evaluation of Work-Zone Design Features to Aid Older Drivers. Paper presented at the Transportation Research Board 88th Annual Meeting, Washington, DC, USA.

John M. Mounce, Gerald Ullman, Geza Pesti, and Valmon Pezoldt. (2007). Guidelines for the Evaluation of Dynamic Message Sign Performance. Texas Transportation Institute, Texas, USA.

Juha Luoma, Pirkko Rama, Merja Penttinen, Virpi Anttila (2000). Effects of variable message signs for slippery road conditions on reported driver behavior. Transportation Research Part F, 2000 Page 75-84, Finland.

Pirkko Rama, Risto Kulmala (2000). Effects of variable message signs for slippery road conditions on driving speed and headways. Transportation Research Part F, 2000 Page 85-94, Finland.

Shuyan He and Wei Guan, (2006). Evaluation of the Effects of Vatriable Message Signs at Urban Traffic Network. Institute of System Engineering, Traffic and Transportation School of Beijing Jiaotong University. IEEE, Beijing.

Wendelboe, Jens Toft (2008). When Under Construction: Copenhagen's Motorway Experience. Traffic Technology International, 2008, p. 74–76.

Tay Richard and De Barros Alex, Effectiveness of Road Safety Messages on Variable Message Signs. Journal of Transportation Systems Engineering and Information Technology. Volume 10, Issue 3, June 2010. Pg 18 - 23.

Yue Li, Yong Bai and Umar Firman. Determining the Effectiveness of PCMS on Reducing Vehicle Speed in Rural Highway Work Zones (2010). Presented at Transportation Research Board 89th Annual Meeting, Washington, D.C.

Xi Chen, Tao Kong and Dongfan Xie (2010). Evaluation of Variable Message Signs on Urban Expressway. IEEE, Beijing, China.

APPENDICES

Appendix A: Data Collection Permissions Correspondences
Appendix B: Hourly Weather Data
Appendix C: Crashes Data
Appendix D: Driver Survey
Appendix E: Worker Survey
Appendix F: Speed Comparison of Before and After for Classes 1, 2 and 3

Appendix A: Data Collection Permissions Correspondences

Department of Transportation Permission letter for Data Collection (1/2)

دائـــرة الـــنـــقـــل
DEPARTMENT OF TRANSPORT

Ref: DOT-MR-MOI-LET-11-00008
Date: 8 / 2 / 2011

Attn: Traffic Engineering Manager
Director of Traffic Engineering and Road Safety
Ministry of the Interior
General Directorate of Abu Dhabi Police
General Administration of Policing Operations
Directorate of Traffic and Patrols

عناية العقيد/ مدير هندسة المرور المحترم ..
مدير إدارة هندسة المرور وسلامة الطرق
وزارة الداخلية
القيادة العامة لشرطة ابوظبي
الإدارة العامة للعمليات الشرطية
مديرية المرور والدوريات
إدارة هندسة المرور وسلامة الطرق

Subject: Permission for Traffic Data Collection
Project: Effectiveness of Portable Variable Message Signs (PVMS)
Survey Location: Abu Dhabi

الموضوع: طلب تصريح لعمل إحصاء مروري
المشروع: فاعلية الإشارات الإلكترونية المتنقلة
الموقع: مدينة أبوظبي

Dear Sir,

تحية طيبة وبعد،

United Arab Emirates University (UAEU) with Department of Transportation (DOT) co-operation are carrying out a Study on the effectiveness of the Portable Variable Message signs on the following roads:

- Arabian Gulf Road in Abu Dhabi.
- Eastern Ring Road in Abu Dhabi.
- Abu Dhabi – Dubai Road (Airport Road):

تقوم جامعة الإمارات العربية المتحدة بالتعاون مع دائرة النقل بإجراء دراسة حول فاعلية الإشارات الإلكترونية المتنقلة على كل من الشوارع التالية:

- شارع الخليج العربي في مدينة أبوظبي.
- شارع الدائري الشرقي في مدينة أبوظبي.
- شارع أبوظبي - دبي (المطار) في مدينة أبوظبي.

"YS Engineering Consultants" has been appointed to collect Traffic Data required for the above roads.

وقد قمنا بتكليف الاستشاري الهندسي واي إس [YS Engineering Consultants] بجمع المعلومات المرورية اللازمة على الشوارع المذكور أعلاه.

The survey locations are marked on the attached sketch.

مرفق مخطط يوضح مواقع جمع المعلومات المرورية.

You are kindly requested to issue a traffic count work permit for
during the period from 5th February 2011 tc 5th March 2011.

لذا نأمل من سيادتكم إصدار تصريح جمع المعلومات المرورية للاستشاري الهندسي خلال الفترة من 5 فبراير 2011 إلى 5 مارس 2011.

If you require further information or clarification, please contact Abdulla Al Falahi on 02-6566142
Email: abdulla.alfalahi@dot.abudhabi.ae

للاستفسار أو لمزيد من الإيضاحات يرجى الاتصال على عبد الله الفلاحي الرقم: 02-6566142 أو عبر البريد الالكتروني abdulla.alfalahi@dot.abudhabi.ae

ص. ب: ٢٠، أبوظبي، الإمارات العربية المتحدة، هاتف: ٦٥٦٦٦٦٦ ٢ ٩٧١+، فاكس: ٦٦٦ ٣٥٩ ٢ ٩٧١+
P.O. Box. 20, Abu Dhabi, United Arab Emirates. Tel.: + 971 2 6566 666, Fax: + 971 2 6359 666
Website: www.dot.abudhabi.ae ,الموقع على الشبكة: E-mail: info@dot.abudhabi.ae ,البريد الالكتروني:

Department of Transportation Permission letter for Data Collection (2/2)

دائـــرة الـــنـــقـــل
DEPARTMENT OF TRANSPORT

Yours Sincerely
Department of Transportation

وتفضلوا بقبول فائق الاحترام والتقدير...
عن/دائـــرة الـــنـــقـــل

Faisal Ahmed Al Suwaidi
General Director – Main Roads

فيصل أحمد السويدي
مدير عام - الطرق الرئيسية

Attachment :

- A sketch showing the traffic survey locations

المرفقات :

- مخطط بمواقع تعداد المرور

ص.ب ٢٠، أبوظبي، الإمـــارات العربيـــة المتحـــدة، هـــاتف: ٦٥٦٦٦٦٦ ٢ ٩٧١+، فـــاكس: ٦٣٥٩٦٦٦ ٢ ٩٧١+
P.O. Box 20, Abu Dhabi, United Arab Emirates. Tel: + 971 2 6566 666, Fax: + 971 2 6359 666
Website: www.dot.abudhabi.ae, الموقع على الشبكة, E-mail: info@dot.abudhabi.ae, البريد الالكتروني

Police Permission for Traffic Data Collection

دولة الإمارات العربية المتحـــــدة
وزارة الداخليـــــــــة
القيادة العامة لشرطة أبوظبي
الإدارة العامة للعمليات الشرطية
مديرية المرور والدوريات
إدارة هندسة المرور وسلامة الطرق

United Arab Emirates
Ministry of Interior
Abu Dhabi Police GHQ
The Gen. Dir of Policing Operations
Traffic and Patrols Directorate
Traffic Engineering Road Safety Dept.

نموذج عمل رقم (17)

Permission for Traffic Data Collection

تصريح أخذ قراءات (تعداد مروري)

رقم التصريح 27213
Thu: 17-03-2011

الشركة:	أي فـور ريمـــورش
منطقة العمل:	خارج مدينة أبوظبي
مكان العمل:	(من جسر القناة - الشاطئ الراحة) - (الشرق الدائري)
مدة التصريح: من:	Fri: 18-03-2011 الى: Fri: 18-03-2011

لا مانع من العمل في وضع أجهزة التعداد المروري في المنطقة حسب المخطط الموضح وعلى الطريق الرئيسي وذلك من الساعة 4.00 صباحاً وحتى الساعة 6.00 صباحاً مع اتخاذ جميع اجراءات السلامة المرورية.*يتم العمل على مراحل مع وجود الدورية مرور اثناء العمل .

لا مانع لدينا من تنفيذ أعمال التعداد المروري، بشرط تطبيق الشروط التالية:-

1. يجب ارتداء قميص عاكس لجميع العاملين.
2. عدم وقوف المركبات أو الأشخاص علي الطرق.
3. يتم الوقوف علي الأرصفة أو الجزر الوسطية خارج حدود الطريق.
4. عدم عبور الطريق إلا من الأماكن المخصصة لعبور المشاه.
5. تعتبر صورة التصريح لاغية، وابقاء النسخة الأصلية من التصريح في موقع العمل وبعكس ذلك بعكس ذلك سيتم إتخاذ الاجراءات القانونية لحين إثبات الشركة المنفذة وحصولها علي تصاريح العمل اللازمة لذلك

الاستشاري:	
مهندس المشروع:	تليفون:
مسؤول الموقع: حماد	تليفون: 0507833188

ع. العميد مهندس/
حسين أحمد الحمادي
مدير مديرية المرور والدوريات

Police Permission for booking a Police Car during Traffic Data Collection

دولة الإمارات العربية المتحدة
وزارة الداخلية
القيادة العامة لشرطة أبو ظبي
الإدارة العامة للعمليات الشرطية
مديرية المرور والدوريات
إدارة هندسة المرور وسلامة الطرق

رقم التصريح:(11/141

التاريخ : 2011/03/17م.

تصريح حجز دورية للأعمال الطرق

ـ لا مانع لدى مديرية المرور والدوريات/ إدارة هندسة المرور وسلامة الطرق / من منح :

الشركة:	اي فور ريسيرش	رقم التصريح	27213
منطقة العمل:	خارج مدينة ابوظبي		
مكان العمل:	من جسر القناه / شاطئ الراحة ـ الشرقي الدائري		

تاريخ التصريح: من:	2011/03/18	إلى:	2011/03/18
توقيت بدء العمل:	4.00 ص	إلى:	6.00 ص

ـ و ذلك حسب الشروط التالية : ـ

1. تواجد دورية من شرطة المرور أثناء فترة العمل.
2. التزام الشركة بكافة إجراءات السلامة المرورية اللازمة والمذكورة بالتصريح.
3. للتواصل مع مكتب المناوب يرجى الاتصال على الرقم : 4196778 – 02 / 3890966 - 050 .
4. ضرورة إبلاغ مكتب التصاريح في حالة إلغاء حجز الدورية قبل العمل بـ 24 ساعة.
5. تعتبر صورة من التصريح لاغيه.

مهندس المشروع:	-	هاتف:	-------
مهندس الموقع:	خالد	هاتف:	050-7833188

ع / العميد مهندس /
حسين احمد الحمادي
مدير مديرية المرور والدوريات

للإستفسار هاتف : 4196843 – 02 مكتب التصاريح
لإستقبال الشكاوي والإقتراحات علي البريد الإلكتروني TRAFFIC_ENG@ADPOLICE.GOV.AE

Police Permission for conducting the driver survey at the driver and car registration department

UNITED ARAB EMIRATES UNIVERSITY

جامعة الإمارات العربية المتحدة

College of Engineering
Associate Dean for Research
and Graduate Studies

كليـــة الهندســـة
العميد المشارك لشؤون البحث العلمي
والدراسات العليا

Date : 07th March, 2011

No. :
Date.:

الرقـم :
التاريخ :

To Whom It May Concern

لمن يهمه الأمر

Project : Effectiveness of Portable Variable Message Signs (PVMS)

المشـروع : فاعلية الإشارات الإلكترونية المتنقله

Survey Location : Abu Dhabi

الموقـــع : مدينة أبوظبي

Dear Sir,

تحية طيبة وبعد،،،

Khalid Al-Zoubi (ID No.200005288), a graduate student in the Civil Engineering Master program at the United Arab Emirates University, is conducting a study to evaluate the use of portable variable message signs (PVMS) to improve safety for motorists and workers at construction zones in Emirates of Abu Dhabi. The research is part of the student's master thesis supervised by professors from the Civil and Environmental Engineering Department at United Arab Emirates University and supported by Department of Transportation.

يقوم الطالب/ خالد إسماعيل الزعبي (الرقم الجامعي 200005288) القيد في برنامج الماجستير بقسم الهندسة المدنية ببحث علمي والمتضمن في رسالة الماجستير حول تقييم اللوحات الالكترونية المتنقلة في تحسين السلامة المرورية على السائقين والعاملين في مناطق الإنشاءات على الطرق في مدينة أبوظبي تحت إشراف أساتذة من قسم الهندسة المدنية والبيئية بجامعة الإمارات العربية المتحدة وبالتعاون مع دائرة النقل.

The study involves the collection of data related to the motorist speeds near the PVMS and distributing a survey forms about the PVMS to measure the effectiveness of the PVMS in improving the traffic safety and increase the awareness of the public on the role of PVMS

وتتضمن الدراسة جمع معلومات حول سرعة السائقين بالقرب من اللوحات الالكترونية وإعداد استبيانات لكل من السائقين والعمال بالقرب من تلك اللوحات بهدف قياس مدى فاعلية هذه اللوحات في تحسين السلامة المرورية ونشر التوعية حول أهمية هذه اللوحات.

We are kindly requesting you to facilitate his task through the data collection stage and provide the required support.
This notice is issued as per the request of the student without any other consequences on the Faculty

وعليه نرجو التكرم من إدارتكم الكريمة الموافقة على دعم الدراسة من ناحية جمع المعلومات وكذلك توفير اللوحات اللازمة خلال فترة الدراسة شاكرين لكم حسن تعاونكم
وقد أعطيت له هذه الشهادة دون أدنى مسئولية على الكلية

وتفضلوا بقبول فائق الاحترام والتقدير ،،،

Yours Faithfully,

Dr. Ali Al Marzouqi
Associate Dean for Graduate Studies and research

تليفون : ٧٦٢١٧٦٥ (٩٧١٣) فاكس : ٧٦٣٢٣٨٢ (٩٧١٣) ص.ب: ١٧٥٥٥ العين - الإمارات العربية المتحدة
Tel.: (9713) 7621765 Fax: (9713) 7632382 P.O. Box : 17555 Al Ain - U.A.E

Accident Report #1

شركة ساعد للأنظمة المرورية

يعتبر هذا التقرير إذنا بإصلاح المركبات ومدة صلاحيته 15 يوما من تاريخ الحادث

تقرير حادث: 01651103270845

بيانات الحادث

تاريخ الحادث	27/03/2011	وقت الحادث	08:44
نوع التقرير	بدون إصابات		
الإمارة	أبوظبي	المدينة	ابوظبي
المنطقة	السمحة	الحوض	لا يوجد تعريف للقطاع
الشارع	شارع الشيخ مكتوم بن راشد	الشارع المقاطع	طريق الروضة الريف
وصف للموقع	قبل جسر السمحه بتجاه ابوظبي		
الاحداثي الشمالي		الإحداثي الشرقي	
نوع الحادث	صدم متتالي	الطقس	صحو
التقاطع	طريق الروضة الريف		
السرعة على الطريق	120	سطح الطريق	معبد
وصف الحادث	اثناء سير المركبه المتضرره للامام صدمتها المركبه المشبيه من الخلف وذلك لعدم ترك مسافه كافيه للعلم		

أسباب الحادث

المركبة	السبب	أخرى	رئيسي؟
10584ابوظبي	عدم ترك مسافة كافية		رئيسي

Accident Report #2

شركة ساعد للأنظمة المرورية

يعتبر هذا التقرير إذنا بإصلاح المركبات ومدة صلاحيته 15 يوما من تاريخ الحادث

تقرير حادث: 01651103270902

بيانات الحادث

تاريخ الحادث	27/03/2011	وقت الحادث	09:01
نوع التقرير	بدون إصابات		
الإمارة	أبوظبي	المدينة	ابوظبي
المنطقة	السمحة	الحوض	لا يوجد تعريف للقطاع
الشارع	شارع الشيخ مكتوم بن راشد	الشارع المقاطع	طريق الروضة الريف
وصف للموقع	قبل جسر السمحه بتجاه ابوظبي		
الاحداثي الشمالي		الاحداثي الشرقي	
نوع الحادث	صدم متتالي	الطقس	صحو
التقاطع	طريق الروضة الريف		
السرعة على الطريق	120	سطح الطريق	معبد
وصف الحادث	اثناء سير المركبه المتضرره تلامام صدمتها المركبه المتسببه من الخلف وذلك لعدم ترك مسافه كافيه للعلم		

أسباب الحادث

المركبة	السبب	أخرى	رئيسي؟
38508 ابوظبي	عدم ترك مسافة كافية		رئيسي

800 (72223)

Appendix B: Driver Survey

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

Research Thesis:

Evaluation of Portable Variable Message Signs to Improve Safety for Motorists and Workers at Construction Zones in Abu Dhabi

موضوع الأطروحه:

تقييم فاعلية اللوحات المرورية الإلكترونية المتنقلة لتحسين السلامة المرورية لمستخدمي الطرق و عمال الإنشاءات على الطرق في أبو ظبي

Driver Survey Form

الاستبيان الخاص بالسائقين

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

Dear evaluator: the United Arab Emirates University (UAEU) in cooperation with the Department of Transportation (DOT) are carrying out a Study on the effectiveness of the Portable Variable Message Signs.

We would therefore appreciate your valuable input by taking few minutes to fill out this survey

عزيزي المقيم: تقوم جامعة الإمارات العربية المتحدة بالتعاون مع دائرة النقل بإجراء دراسه حول فاعلية الإشارات الإلكترونية المتنقلة.

لذلك نقدر تعاونكم في امضاء بعض من وقتكم في ملئ الاستبيار التالي بارائكم القيمه.

Opinion Survey*

Effectiveness of Portable Variable Message Signs in Abu Dhabi City

استطلاعات الرأي

فاعلية الاشارات الالكترونية المتنقلة في مدينة أبوظبي

1) For Comparison purposes, please tell us your gender, age group, and educational attainment.

__Male __Female

__18–25 year __26–35 year
__36–64 year __>65year

__Less than high shool __High school diploma
__College __Graduate degree(s)

1) لأهداف تحليلية وللمقارنة، يرجى ذكر الجنس والعمر والمؤهل العلمي.

__ ذكر __ أنثى

__ 18–25 سنة __ 26-35 سنة
__ 36–64 سنة __ أكبر من 65 سنة

__ أقل من ثانوية عامه __ ثانوية عامه او دبلوم
__ جامعي __ دراسات عليا

2) How long you had a valid driving license (UAE)?

__less than 1 year __1 – 3 years
__3 – 5 years __ 5 –10 years
__More than 10 years

2) منذ متى تحمل رخصة قيادة (دولة الإمارات) صالحة؟

__ أقل من سنة __ 1 سنة – 3 سنوات
__ 3 – 5 سنوات __ 5 – 10 سنوات
__ أكثر من 10 سنوات

3) How often do you travel on Abu Dhabi Highways and Main Roads

☐ Daily ☐ Weekly
☐ Monthly ☐ Less than Monthly

3) كم من المعتاد القيادة على شوارع ابوظبي الخارجية والرئيسية؟

☐ يوميا ☐ أسبوعيا
☐ شهريا ☐ أقل من شهريا

4) Are you familiar with what portable variable message sign are?

Never heard of them — Very Familiar

0 1 2 3 4

4) ما مدى معرفتك بالإشارات الالكترونية المتنقلة؟

مألوفه — غير مألوفه

4 3 2 1 0

5) Is the information posted on portable variable message sign accurate?

☐ Yes ☐ No

5) هل المعلومة المعروضه على شاشة الإشارة الإلكترونية دقيقة ؟

☐ نعم ☐ لا

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

6) How **easy** in general are you able to **see** and read the messages

6) مدى **صعوبة/سهولة رؤية** وقراءة الرسالة على اللوحة الالكترونية المتنقلة

Very Difficult — Very Easy

0 1 2 3 4

صعبة جدا — سهلة جدا

4 3 2 1 0

7) **Reasons of difficulty seeing** and reading the messages on the portable variable message signs
(Rate 1-6 with 1 being the most important)

___My view of the sign is blocked by traffic
___The messages are too long
___The messages aren't updated frequently enough
___The messages change too frequently
___The lettering on the sign is too small
___Location of Portable Message Sign on Road

7) **اسباب صعوبة رؤية** وقراءة الرسالة المعروضة على شاشة الإشارة الالكترونية المتنقلة بحسب رأيك **بسبب**
(رتبها من 1 (الأكثر اهمية) إلى 6)

___ لحجبها بواسطة الحركة المرورية
___ الرسالة المعروضة طويلة
___ الرسالة المعروضة لايتم تحديثها بشكل كافي
___ الرسالة المعروضة تتغير بشكل مستمر
___ أحرف رسالة الاشاره الالكترونية صغيرة
___ مكان الاشارة الالكترونية المتنقله على الشارع

8) How often do you **read** the electronic message posted on portable variable message sign?

☐ Always or Most of the Time
☐ Sometimes
☐ Rarely or Never

8) هل **تقرأ** الرسائل المعروضه على الاشارات الإلكترونيه المتنقله؟

☑ دائما أو معظم الوقت
☐ احيانا
☐ نادرا او ابدا

9) The portable variable message sign you have seen show **warning about**: (Select any)

☐ Weather Related Advisory Activities
☐ Accidents and/or Road Hazard Warnings
☐ Construction/Maintenance
☐ Road Closure and/or Detour
☐ Other (Please specify)

9) الرسالة الموضحه على الإشاره الالكترونية المتنقله التى شاهدتها كانت **حول**: (اختر أي من الخيارات)

☐ حالة الطقس
☐ حادث مروري / تحذير حول حالة الطريق
☑ أعمال الطرق / صيانة الطرق
☑ اغلاق مسار / تحويل مسار
☐ غير ذلك (يرجى التحديد)

10) What **information would be most important** to you to be displayed on portable variable message sign?

(Rate 1-5 with 1 being the most important)

___Weather Related Advisory Activities
___Accidents and/or Road Hazard Warnings
___Construction/Maintenance
___Road Closure and/or Detour
___Other (Please specify) _____

10) كمستخدم للطريق ماهو **مضمون الرسالة التي تعتبرها اكثر اهمية** لعرضها على شاشة الإشارة الإلكترونية المتنقله؟

(رتبها من 1 (الأكثر أهمية) إلى 5)

___حالة الطقس
___حادث مروري / تحذير حول حالة الطريق
✓ أعمال الطرق / صيانة الطرق
✓ اغلاق مسار / تحويل مسار
___غير ذلك (يرجى التحديد) _____

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

11) Please indicate how strongly you **agree or disagree** with the following statements.
The choices are:

5	4	3	2	1
Strongly Agree	Agree	Nuteral	Disagree	Strongly Disagree

Overall, the implementations of portable variable message sign have been **positive**.
5 4 3 2 1

Portable variable message sign have personally **helped me while traveling**.
5 4 3 2 1

Roadways are **safer** as a result of portable variable message sign.
5 4 3 2 1

I would like to see **more** portable variable message sign in the future.
5 4 3 2 1

The information provided on portable variable message sign is **reliable**?
5 4 3 2 1

12) How **useful** is the information displayed on portable variable message signs for:

Accidents affecting traffic

Not Helpful — Very Helpful
0 1 2 3 4

Emergency situations (Natural disasters, etc)

Not Helpful — Very Helpful
0 1 2 3 4

Current Travel Time

Not Helpful — Very Helpful
0 1 2 3 4

Weather information

Not Helpful — Very Helpful
0 1 2 3 4

11) يرجى **تقييم مدى رضاك** حول الأمور التالية:
التقييم حسب مدى الرضى:

5	4	3	2	1
موافق بشده	موافق	محايد	غير موافق	غير موافق بشده

بشكل عام، تطبيق الإشارات الالكترونية المتنقلة **ايجابي**
5 4 3 2 1

لقد **ساعدتني** الإشارات الإلكترونية المتنقله خلال القياده
5 4 3 2 1

الطرق بوجود الإشارات الإلكترونية المتنقله أصبحت **أكثر سلامة**
5 4 3 2 1

أفضل أن أرى **الكثير** من الإشارات الإلكترونية المتنقله في المستقبل
5 4 3 2 1

المعلومة المعروضة على شاشة الإشارة الإلكترونية المتنقلة **حقيقية يمكن الوثوق بها؟**
5 4 3 2 1

12) **الفائدة** المرجوة من عرض الرسائل على شاشة الإشارة الإلكترونية المتنقلة:

التحذير من وجود حادث مروري

غير مفيده — مفيده جدا
4 3 2 1 0

التحذير من وجود حالة طوارئ (كارثة طبيعيه)

غير مفيده — مفيده جدا
4 3 2 1 0

تقدير الوقت المستغرق للوصول لنقطة ما

غير مفيده — مفيده جدا
4 3 2 1 0

معرفة حالة الطقس

غير مفيده — مفيده جدا
4 3 2 1 0

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

Traffic Congestion

Not Helpful — Very Helpful

0 1 2 3 4

معرفة مدى وجود زحمة المرورية

غير مفيده — مفيده جدا

0 1 2 3 4

Current Roadwork

Not Helpful — Very Helpful

0 1 2 3 4

معرفة إمكانية وجود أعمال الطرق

غير مفيده — مفيده جدا

0 1 2 3 4

Special Event information (Fairs, Sporting Events)

Not Helpful — Very Helpful

0 1 2 3 4

عرض حدث ما (عروضات، حدث رياضي)

غير مفيده — مفيده جدا

0 1 2 3 4

Warning about Road Hazard

Recommended alternate routes (when roads are closed or there is an accident ahead)

Not Helpful — Very Helpful

0 1 2 3 4

تحذير لحالة الطريق
استخدم طرق بديلة
(عندما يتم إغلاق طريق أو حادث مروري)

غير مفيده — مفيده جدا

0 1 2 3 4

13) Any comments on the subject?

13) أي إضافات على موضوع الاستبيان ؟

الدكتار من خرد اللوحات في الشوارع.

14) In General the survey was:

Poor — Excellent

0 1 2 3 4

14) الاستبيان بشكل عام:

مقبول — ممتاز

0 1 2 3 4

15) Any comments to improve the survey?

15) هل هنالك أي تعليقات لتحسين الاستبيان؟

لا

Thank you very much for your cooperation

Eng. Khalid Al-Zoubi
Civil Engineering Master Program
United Arab Emirates University

P.O Box, 27594
Mobile +971 50 783 3188
Fax +971 2 417 3001
Email: 200005288@uaeu.ac.ae

نشكركم جزيلاً لتعاونكم معنا

م. خالد الزعبي
برنامج الماجستير – قسم الهندسة المدنية
جامعة الإمارات العربية المتحدة

ص.ب 27594
متحرك 971 50 7833188+
فاكس 971 2 417 3001+
بريد الكتروني 200005288@uaeu.ac.ae

Appendix C: Worker Survey

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

Research Thesis: موضوع الأطروحة:

Evaluation of Portable Variable Message Signs to Improve Safety for Motorists and Workers at Construction Zones in Abu Dhabi

تقييم فاعلية اللوحات المرورية الإلكترونية المتنقلة لتحسين السلامة المرورية لمستخدمي الطرق و عمال الإنشاءات على الطرق في أبو ظبي

Work Zone Survey Form الاستبيان الخاص بمواقع الإنشاءات

(2)

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

Dear evaluator: the United Arab Emirates University (UAEU) in cooperation with the Department of Transportation (DOT) are carrying out a Study on the effectiveness of the Portable Variable Message Signs

We would therefore appreciate your valuable input by taking few minutes to fill out this survey

عزيزي المقيم. تقوم جامعة الإمارات العربية المتحدة بالتعاون مع دائرة النقل باجراء دراسه حول فاعلية الإشارات الالكترونية المتنقلة.

لذلك نقدر تعاونكم في امضاء بعض من وقتكم في ملئ الاستبيان التالي بارائكم القيمه

Opinion Survey*

Effectiveness of Portable Variable Message Signs in Abu Dhabi City

1) **For Comparison purposes**, please tell us your gender, age group, and educational attainment.

✓Male __Female

✓18–25 year __26–35 year
__ 36–64 year __>65year

__Less than high shool ✓High school diploma
__College __Graduate degree(s)

2) Job:
__Site Engineer ✓Administration
__Dnver (Light/Heavy) __Supervisor
__ Labour

3) How long you had a **valid driving license** (UAE) - (If you have)?
__less than 1 year ✓1 – 3 years
__3 – 5 years __ 5 –10 years
__More than 10 years __N/A

4) How **often** do you travel through construction zone on Abu Dhabi Highways and Main Roads (If Driving License Available)
☑ Daily ☐ Weekly
☐ Monthly ☐ Less than Monthly

5) Are you **familiar** with what portable variable message sign are?

Never heard of them — Very Familiar

0 1 2 3 ✓4

استطلاعات الرأي

فاعلية الإشارات الالكترونية المتنقلة في مدينة أبوظبي

1) **لأهداف تحليلة وللمقارنة**، يرجى ذكر الجنس والعمر والموهل العلمي.

__ذكر __أنثى

__ 18–25 سنة __ 26-35 سنة
__ 36–64 سنة __ أكبر من 65 سنه

__ أقل من ثانوية عامه __ثانوية عامه أو دبلوم
__ جامعي __ دراسات عليا

2) المهنة:
__مهندس موقع __ الإدارة
__سائق (خفيف/ثقيل) __مشرف عمال
__عامل

3) منذ متى تحمل **رخصة قيادة** (دولة الإمارات) **صالحة**؟

__أقل من سنة __ 1 سنة – 3 سنوات
__3 – 5 سنوات __ 5 – 10 سنوات
__ أكثر من 10 سنوات __ لا املك

4) كم من **المعتاد** القيادة خلال منطقة الانشاءات على طرق أبوظبي الخارجية والرئيسية؟ (رخصة قيادة متوفرة)

☐ يوميا ☐ أسبوعيا
☐ شهريا ☐ أقل من شهريا

5) ما مدى **معرفتك** بالإشارات الالكترونية المتنقلة؟

غير مألوفه — مألوفه

4 3 2 1 0

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

6) In your opinion, the best equipment used for Traffic Safety at the work zone is:

(Rate 1-4 with 1 being the best)

2 Fixed Signs
1 Portable Variable Message Signs
3 Flagging
___Others (Please Specify)_____

6) برايك ماهي افضل الوسائل المتبعه للحفاظ على السلامة المرورية في مناطق الإنشاءات:

(رتبها من 1 (الأفضل) إلى 4)

___الإشارات الثابتة
___الإشارات الإلكترونية المتنقلة
___من خلال الامساك برايه ما (التلويح بالراية)
___غير ذلك (يرجى التحديد) _____

7) In your opinion, How **useful** Portable Variable Message Signs at Work Zones?

Not Useful — Very Useful

0 1 2 3 4

7) فائدة الإشارات الإلكترونية المتنقلة في مناطق الانشاءات بحسب رأيك:

غير مفيده — مفيده جدا

4 3 2 1 0

8) You **prefer** the message on the portable variable message signs to be about:
(Rate 1-6 with 1 being the most important)

3 Work Zone (Work Zone A head)
2 Work Zone Workers (Be Aware – Workers)
4 Speed (Speed Limit:##Km/hr)
5 Information (Expected Delay)
1 Advise (Use Alternative Roads)
___Others (Please Specify) _____

8) أفضل الرسالة المعروضة على شاشة الاشاره الالكترونة المتنقلة في منطقة العمل أن تكون حول:
(رتبها من 1 (الاكثر أهمية) إلى 6)

___خاصة بمنطقة الإنشاءات (احذر منطقة انشاءات)
___خاصة بعمال الإنشاءات (احذر عمال طرق)
___خاصة بالسرعه (السرعه المحدد ##كم/ساعه)
___لتقديم معلومة (توقع التاخير - منطقة انشاءات)
___بصيحة (استخدم طرق بديلة)
___غير ذلك (يرجى التحديد)_____

9) The portable variable message sign you have seen near the Construction Zone show **warning about**. (Select any)

☑ Lane Closure
☑ Work Zone A head
☐ Use Alternative Roads
☐ Speed Limits: ##Km/hr
☐ Other (Please specify)

9) الرسالة الموضحه على الإشارة الالكترونية المتنقله التى شاهدتها في منطقة العمل حول: (اختر أي من الخيارات)

☐ اغلاق مسار
☐ امامك منطقه عمل
☐ استخدم طرق بديلة
☐ السرعه المحدد: ##كم/ساعه
☐ غير ذلك (يرجى التحديد)

10) How often do you **read** the electronic message posted on portable variable message sign?

☑ Always or Most of the Time
☐ Sometimes
☐ Rarely or Never

10) هل تقرأ الرسائل المعروضه على الإشارات الالكترونية المتنقله؟

☐ دائما او معظم الوقت
☐ أحيانا
☐ نادرا او أبدا

UNITED ARAB EMIRATES UNIVERSITY
College of Engineering
Department of Civil & Environmental Engineering
P.O. Box 17555 - Al Ain – United Arab Emirates

11) Is the information posted on portable variable message sign accurate?

☐ Yes ☒ No

12) Please indicate how strongly you **agree or disagree** with the following statements.
The choices are:

5	4	3	2	1
Strongly Agree	Agree	Nuteral	Disagree	Strongly Disagree

Overall, the implementations of portable variable message sign have been positive.
~~5~~ 4 3 2 1

Portable variable message sign have personally **helped me while working**.
5 ~~4~~ 3 2 1

Work Zones are safer as a result of portable variable message sign.
5 ~~4~~ 3 2 1

I would like to see more portable variable message sign in the future.
~~5~~ 4 3 2 1

The information provided on portable variable message sign is reliable?
5 4 ~~3~~ 2 1

13) Any comments on the subject?

14) In General the survey was:

Poor ⟵ ⟶ Excellent
0 1 2 3 ~~4~~

15) Any comments to improve the survey?

Thank you very much for your cooperation

Eng. Khalid Al-Zoubi
Civil Engineering Master Program
United Arab Emirates University
P.O Box, 27594
Mobile +971 50 783 3188
Fax +971 2 417 3001
Email: 200005288@uaeu.ac.ae

11) هل المعلومة المعروضه على شاشة الإشارة الإلكترونية بدقيقة ؟

☐ نعم ☐ لا

12) يرجى تقييم مدى رضاك حول الأمور التالية:
التقييم حسب مدى الرضى:

5	4	3	2	1
موافق بشده	موافق	محايد	غير موافق	غير موافق بشده

بشكل عام، تطبيق الإشارات الالكترونية المتنقلة إيجابي
5 4 3 2 1

لقد ساعدتني الإشارات الإلكترونية المتنقله خلال عملي
5 4 3 2 1

مناطق الإنشاءات بوجود الإشارات الإلكترونية المتنقله أصبحت اكثر سلامة
5 4 3 2 1

أفضل أن أرى الكثير من الإشارات الإلكترونية المتنقله في المستقبل
5 4 3 2 1

المعلومة المعروضة على شاشة الإشارة الإلكترونية المتنقلة حقيقية؟
5 4 3 2 1

13) أي إضافات على موضوع الاستبيان ؟

14) الاستبيان بشكل عام:

ممتاز ⟵ ⟶ مقبول
4 3 2 1 0

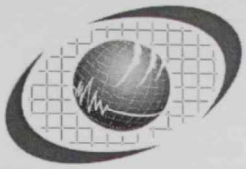
15) هل هناك أي تعليقات لتحسين الاستبيان؟

نشكركم جزيلاً لتعاونكم معنا

م. خالد الزعبي
برنامج الماجستير – قسم الهندسة المدنية
جامعة الإمارات العربية المتحدة
ص.ب 27594
متحرك 50 7833188 971+
فاكس 3001 2 417 971+
بريد إلكتروني 200005288@uaeu.ac.ae

Appendix D: Hourly Weather Data

To :UAEU
Date : 29/06/2011
Subject : Temperature (c°), Relative Humidity(%) & wind speed (m/s)



Temperature (c°), Relative Humidity(%), wind speed (m/s) & Weather

Abu Dhabi Int'l Airport

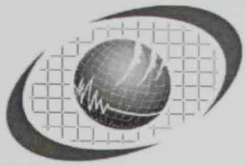
PERIOD : March 18, 2011 – March 28, 2011

YEAR	MONTH	DATE	HOUR	wind speed (m/s)	Temperature (c°)	Relative Humidity (%)	Weather
2011	3	18	0	3.6	20.0	77	0
2011	3	18	1	3.6	19.8	79	0
2011	3	18	2	3.1	19.7	81	0
2011	3	18	3	2.6	19.6	81	0
2011	3	18	4	2.6	19.1	82	0
2011	3	18	5	2.1	17.9	84	0
2011	3	18	6	2.1	17.5	86	0
2011	3	18	7	2.6	18.6	85	0
2011	3	18	8	4.1	20.2	81	Haze
2011	3	18	9	4.6	21.7	73	0
2011	3	18	10	5.7	22 9	64	0
2011	3	18	11	5.7	23.6	60	0
2011	3	18	12	6.2	24.6	57	0
2011	3	18	13	5.7	25.1	51	0
2011	3	18	14	6.7	25.4	47	0
2011	3	18	15	7.7	25.0	51	0
2011	3	18	16	7.7	24.4	56	0
2011	3	18	17	7.2	23.6	57	0
2011	3	18	18	6.2	22.7	62	0
2011	3	18	19	5.7	22.0	65	0
2011	3	18	20	4.6	21 5	69	0
2011	3	18	21	5.1	21.2	69	0
2011	3	18	22	4.6	20.7	70	0
2011	3	18	23	4.6	20.3	71	0
2011	3	19	0	3.1	20.3	72	0

National Center of Meteorology & Seismology , Meteorological department , PO Box 4815 Abu Dhabi , UAE

Tel. 02-2227777, Fax. 02-6672976, A. Machine 70001000, Web site: http://www.ncms.ae/- E-Mail : climate@ncms.ae

To :UAEU
Date : 29/06/2011
Subject : Temperature (c°), Relative Humidity(%) & wind speed (m/s)



Temperature (c°), Relative Humidity(%) & wind speed (m/s)

Abu Dhabi

PERIOD : March 18, 2011 - March 28, 2011

YEAR	MONTH	DATE	HOUR	wind speed (m/s)	Temperature (c°)	Relative Humidity (%)
2011	3	18	0	5.5	20.3	70.7
2011	3	18	1	4.8	20.3	70.8
2011	3	18	2	4.8	20.1	70.5
2011	3	18	3	4.3	20.1	71.2
2011	3	18	4	3.3	20.1	72.6
2011	3	18	5	3.1	20.1	73
2011	3	18	6	4.6	20.2	72.9
2011	3	18	7	5.5	20.3	72.8
2011	3	18	8	4.1	20.9	70.5
2011	3	18	9	4.7	21.6	66.8
2011	3	18	10	5.5	21.9	64.3
2011	3	18	11	4.2	22.6	64.4
2011	3	18	12	4.7	22.9	62.2
2011	3	18	13	5.0	22.9	61.7
2011	3	18	14	5.4	23.4	60.1
2011	3	18	15	7.5	23.2	60
2011	3	18	16	6.4	23.2	60.9
2011	3	18	17	6.6	22.6	61.4
2011	3	18	18	6.3	22.3	62.5
2011	3	18	19	6.0	21.9	63.3
2011	3	18	20	6.6	21.7	63.7
2011	3	18	21	6.5	21.5	63.1
2011	3	18	22	4.9	21.3	64.2
2011	3	18	23	4.2	21.3	65
2011	3	19	0	4.0	21.3	64.9
2011	3	19	1	4.2	21.0	65.3

National Center of Meteorology & Seismology , Meteorological department , PO Box 4815 Abu Dhabi , UAE

Tel. 02-2227777, Fax. 02-6672976, A. Machine 700013000, Web site: http://www.ncms.ae/- E-Mail : climate@ncms.ae

Appendix E: Crashes Data

UNITED ARAB EMIRATES
MINISTRY OF INTERIOR
Abu Dhabi Police GHQ.
The Traffic Section
The Casualty Level-Ministry

دولـة الإمارات العربية
المتحدة
وزارة الداخلية
القيادة العامة لشرطة ابوظبي
مديرية المرور و الدوريات

من تاريخ 2008/01/01 الى 2010/12/31

			بسيطة	متوسطة	بليغة	وفاة	المجمـوع
ابوظبي	2008	(شارع السلام (8	128	37	7	1	173
		شارع الشيخ مكتوم بن راشد	154	134	29	32	349
		طريق أم النار / الشهامة	75	44	8	11	138
		Total	357	215	44	44	660
	2009	(شارع السلام (8	35	25	4	4	68
		شارع الشيخ مكتوم بن راشد	139	123	49	35	346
		طريق أم النار / الشهامة	59	49	4	6	118
		Total	233	197	57	45	532
	2010	(شارع السلام (8	20	18	4	1	43
		شارع الشيخ مكتوم بن راشد	154	133	28	31	346
		طريق أم النار / الشهامة	69	47	4	5	125
		Total	243	198	36	37	514
المجموع			833	610	137	126	1706

من تاريخ 2008/01/01 إلى 2010/12/31

2.008	ابوظبي	2178
	العين	546
	المنطقة الغربية	361
	المجموع	3085
2.009	ابوظبي	2210
	العين	675
	المنطقة الغربية	334
	المجموع	3219
2.010	ابوظبي	1718
	العين	604
	المنطقة الغربية	332
	المجموع	2654

Appendix F: Speed Comparison of Before and After for Classes 1, 2 and 3

Work Zone – Al Samha Area, E11 Road

i. Comparison of Before and After for Class 1 – Individual days

Vehicles of Class 1 were compared for the vases of Before PVMS and After PVMS based on the collected speed data for each individual day. The MOE's results were detailed as follows:

Average Speed

Comparing the Before PVMS and After PVMS, Table F.1 indicates that there is an increase of about 1% in After PVMS case for Saturday and Sunday days. There is a reduction of 1% on Monday. This difference during the three days is considered to be not significant. There was no reduction in average speed with the speed limit of 100 km/hr (Posted speed is 80km.hr including margin of 20km/hr) for both before and after cases. The average speed for both cases is more than the speed limit about 27±1km/hr.

In addition, the average speed for the upstream after PVMS case is increased on Saturday by less than 1% and decreased by 1% to 2% on Sunday and Monday. The downstream average speed for the after PVMS case is increased by 1% to 3% compared to the average speed of the before case. This comparison shows some changes in average speeds when no statistical significance was present.

Changes in 85th percentile Speed

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.1 at the 95 percent confidence level shows that there is a minor reduction in the after 85th percentile speeds which is about 1km/hr than the 85th percentile speeds of the Before PVMS case.

Table F.1: MOE's results for Construction Site (Class 1 – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	127	143	↑ 1	↑ 1%
	After	128	142		
	Upstream	125	143	↓ 2	↓ 2%
	Downstream	129	145	↑ 2	↑ 1%
SUN	Before	127	143	↑ 1	↑ 1%
	After	128	143		
	Upstream	125	143	↓ 2	↓ 2%
	Downstream	129	146	↑ 2	↑ 1%
Mon	Before	127	143	↓ 1	↓ 0%
	After	127	142		
	Upstream	124	143	↓ 3	↓ 2%
	Downstream	128	145	↑ 1	↑ 1%

Change in Proportions of Speeding Vehicles

Figure F.1 illustrates the frequencies of the observed speeds for Class 1 grouped in 10km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds in work zones when the PVMS sign was installed. It's noticeable that high speeds observations is reduced after installing the PVMS. The reduction is about 0.55% for the 150-160 km/hr speeds and 0.18% for the 140-150 km/hr speeds. The speeds of 120-140 km/hr are increased during the after installing PVMS which mean that high speeds were reduced and shifted back to the speeds of 120-140km/hr that is close to the average speed for both cases before and after PVMS. The figure illustrates that the low speeds of 60km/hr-120 km/hr is reduced after installing PVMS, which means that the drivers with low speeds increase their speed close to the average which is 120km.hr – 140km/hr.

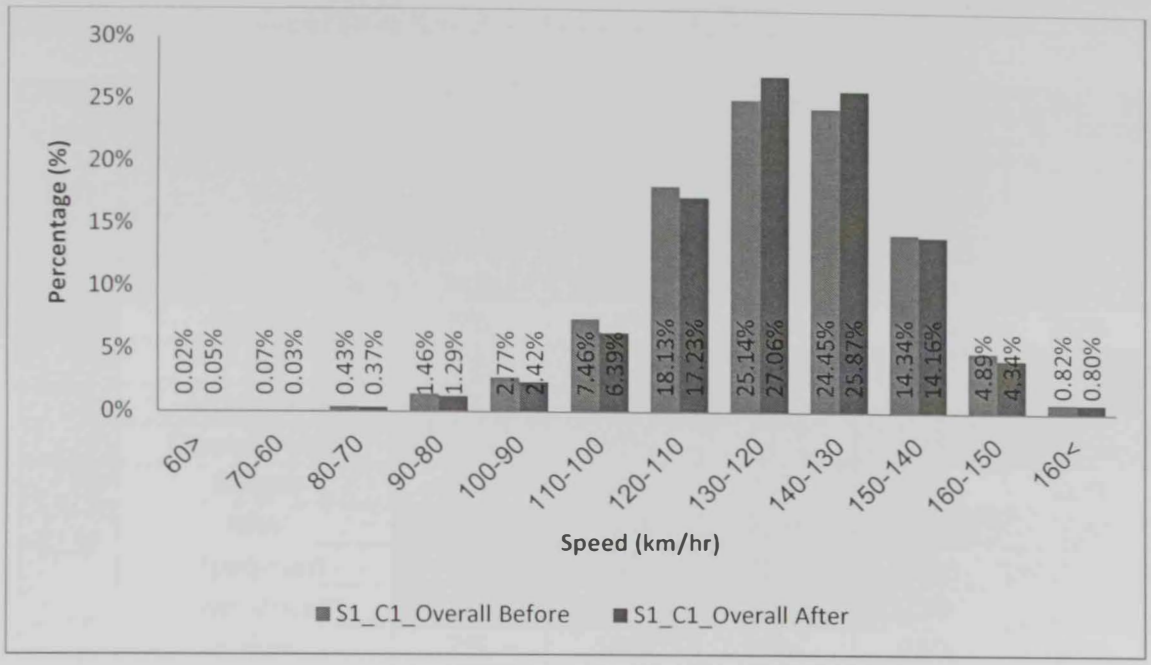


Figure F.1: Percentages of High Speeds for E11 Road (Work Zone) for Class 1

Table F.2 shows the percentages of higher-speed Class1 vehicle's exceeding the speed limit. The overall figures show that about 95% of the vehicles are not complying with the speed limit. In this case, comparison with the posted speed limit is not sufficient. Table F.2 shows the difference between the percentage of Class1 vehicle's exceeding speed limits for the After PVMS case compared with the percentage of the vehicles exceeding speed limit for the before PVMS case. In general, vehicles exceeding the speed limit from more than 0 km/hr to 30 km/hr over speed limit are reduced after installing the PVMS by about 1% to 2%. On other hand, Class 1 vehicles exceeding the speed limit from 30 km/hr to 40km/hr over speed limit are increased after installing the PVMS by about 2% to 3%. Vehicles exceeding the speed limit more than 40 km/hr over speed limit has no change after installing PVMS.

Table F.2: Percentages of High Speeds at Work zone for Class 1.

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	8%	18%	24%	24%	20%
	After	6%	17%	27%	26%	20%
	Upstream	13%	20%	23%	17%	21%
	Downstream	7%	18%	24%	23%	24%
SUN	Before	7%	18%	25%	24%	20%
	After	6%	17%	27%	27%	20%
	Upstream	12%	20%	23%	18%	21%
	Downstream	8%	18%	23%	23%	25%
Mon	Before	7%	18%	26%	25%	20%
	After	7%	17%	28%	26%	18%
	Upstream	12%	20%	22%	18%	20%
	Downstream	8%	18%	23%	22%	25%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speeds

2 sample t-test: Speed Means for Before and After PVMS

The results indicate same observations of All classes cases. As shown in Table F.3 the results indicate that there is statistical significant difference between the speed means of Before PVMS with the After PVMS on Saturday and Sunday when p-value is < 0.005. But t-values indicate that the difference is in negative so the speed means for the Before PVMS case is less than the speed means for the After PVMS case. On Monday, the t-value is in positive that indicates the speed means for the Before PVMS case is greater than the After PVMS case and p-value is > 0.005 which indicate that there is no statistical significant difference.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

The results indicate same observations of All classes cases. The comparison in this case is not applicable where speed limits are different at the upstream and downstream with the PVMS location. The upstream t-value and p-values indicate that there is no statistical significant difference between the upstream speed means of the After case and the Before case and Speed means for the upstream is greater than the speed means for the Before case. The downstream of the After PVMS case t-values are in negative so that the speed means for the Before case is greater than the speed means for the downstream of the After PMVS case with statistical significant difference.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (100km/hr)

As shown in Table F.3, there is no statistical difference between the Before and After PVMS cases with the speed limit where p-value is greater than 0.005. The positive t-values indicates that speed means for the Before and After PVMS cases are greater than speed limit. It's clear that t-values are gradually decreased over the days.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (140km/hr)

p-values indicate that there is a statistical significant difference of the speed means with the speed limit. But negative t-values indicate that the upstream and downstream speed means are less than the speed limit.

Table F.3: t-Test results for Work zone (Class 1 – individual days)

Site 1 – Class 1	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	-6.37	-8.65	4.13
	p-value	0	0	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	20.13	18.61	22.43
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	-15.22	-12.78	-7.05
	p-value	0	0	0
1 sample t-test: Speed Means for Before PVMS and Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	368.86	330.9	311.12
	p-value	1	1	1
1 sample t-test: Speed Means for After PVMS and Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	394.77	368.2	313.1
	p-value	1	1	1
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-192.7	-179.26	-164.9
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-147.43	-135.84	-125.07
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

ii. Comparison of Before and After for Class 2 – Individual days

Vehicles of Class 2 were compared for the vases of Before PVMS and After PVMS based on the collected speed data for each individual day. The results were as follows:

Average Speed

Comparing the Before PVMS and After PVMS, Table 4.4 indicates that there is an increase of about 3% in After PVMS case for all three days. There was no reduction in average speed with the speed limit of 100 km/hr (Posted speed is 80km.hr including margin of 20km/hr) for both before and after cases. The average speed for both cases is more than the speed limit with about 4±4km/hr. In addition, the average speed for the upstream and downstream for the after PVMS case is deceased by 3% to 10%.

Table F.4: MOE's results for Construction Site (Class 2 – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	105	132	↑ 3	↑ 3%
	After	108	133		
	Upstream	95	113	↓ 10	↓ 10%
	Downstream	102	129	↓ 3	↓ 3%
SUN	Before	103	131	↑ 3	↑ 3%
	After	106	132		
	Upstream	93	108	↓ 10	↓ 9%
	Downstream	100	126	↓ 3	↓ 3%
Mon	Before	100	127	↑ 3	↑ 3%
	After	104	130		
	Upstream	92	107	↓ 8	↓ 8%
	Downstream	98	123	↓ 6	↓ 2%

Changes in 85th percentile Speed

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.3 at the 95 percent confidence level shows that there is a minor increase in the after 85th percentile speeds with about 1 km/hr to 3 km/hr than the 85th percentile speeds of the Before PVMS case.

Change in Proportions of Speeding Vehicles

Figures F.2 illustrates the frequencies of the observed speeds for Class 2 grouped in 10km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds in work zones when the PVMS sign was installed. It's noticeable that high speeds observations for speed range 100km/hr to more than 160 km/hr is increased after installing the PVMS. The vehicles of Class 2 with speed range of more than 60km/hr to 100km/hr were reduced after installing the PVMS.

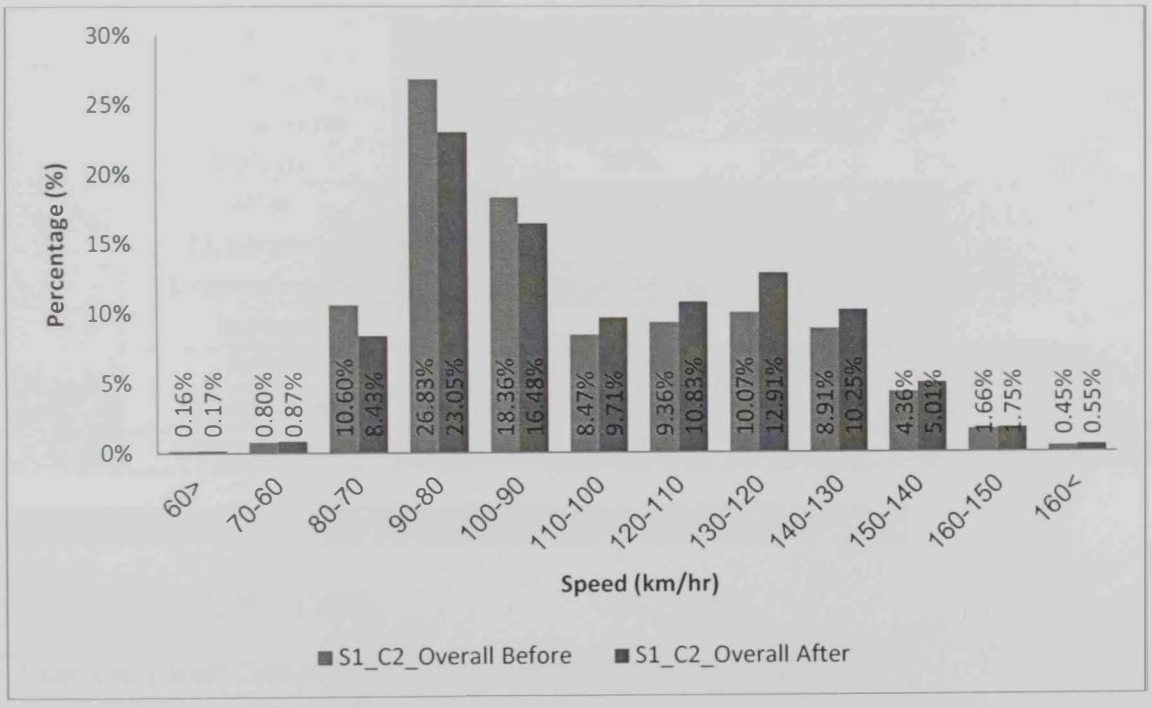


Figure F.2: Percentages of High Speeds for E11 Road (Work Zone) for Class 2

Table F.5 shows the percentages of higher-speed Class 2 vehicle's exceeding the speed limit. The overall figures show that about 55% of the Class 2 vehicles are not complying with the speed limit. The difference between the percentage of Class 2 vehicle's exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case as show in Table F.5. In general, Class 2 vehicles exceeding the speed limit are increased after installing the PVMS by about 1% to 2%.

Table F.5: Percentages of High Speeds at Work zone for Class 2

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	9%	10%	11%	10%	8%
	After	10%	12%	14%	11%	8%
	Upstream	9%	5%	5%	3%	4%
	Downstream	10%	7%	6%	5%	5%
SUN	Before	8%	10%	9%	9%	7%
	After	10%	10%	13%	10%	7%
	Upstream	9%	4%	4%	3%	3%
	Downstream	11%	7%	7%	6%	6%
Mon	Before	8%	8%	9%	8%	5%
	After	9%	10%	12%	9%	6%
	Upstream	10%	4%	4%	3%	3%
	Downstream	9%	8%	6%	6%	5%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speed

2 sample t-test: Speed Means for Before and After PVMS

As shown in Table F.6 the results indicate that there is statistical significant difference between the speed means of Before PVMS with the After PVMS when p-value is <0.005.

But t-values indicate that the difference is in negative so the speed means for the Before PVMS case is less than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

The upstream t-value and p-values indicate that there is no statistical significant difference between the upstream and downstream speed means of the After case with the Before case. The positive t-value indicate that speed means for the Before case is less than the speed means for the upstream and downstream of the After PMVS case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (100km/hr)

As shown in Table F.6, there is no statistical difference between the Before PVMS cases with the speed limit where p-value is greater than 0.005. The positive t-values indicates that speed means for the Before and After PVMS cases are greater than speed limit. It's clear that t-values are gradually decreased over the days.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (140km/hr):

p-values indicate that there is a statistical significant difference of the speed means with the speed limit. But negative t-values indicate that the upstream and downstream speed means are less than the speed limit.

Table F.6: t-Test results for Work zone (Class 2 – individual days)

Site 1 – Class 2	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	-6.47	-7.18	-7.84
	p-value	0	0	0
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	34.82	22.74	18.35
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	6.63	6.53	4.74
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	16.07	8.32	0.45
	p-value	1	1	0.673
1 sample t-test: Speed Means for After PVMS and Speed Limit (100km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	28.07	19.71	11.67
	p-value	1	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-161.81	-165.25	-163.56
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-115.96	-120.41	-122.5
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

iii. Comparison of Before and After for Class 3 – Individual days

Vehicles of Class 3 were compared for the cases of Before PVMS and After PVMS based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Comparing the Before PVMS and After PVMS, Table F.7 indicates that there is an increase of about 1% to 2% in After PVMS case for Saturday and Monday days. There is a reduction of 1% in the average speed after installing PVMS on Sunday day. There was no reduction in average speed with the speed limit of 80 km/hr (Posted speed is 80km.hr) for both before and after cases. The average speed for both cases is more than the speed limit with about 20km/hr. In addition, the average speed for the upstream and downstream for the after PVMS case is deceased by 2% to 5%.

Table F.7: MOE's results for Construction Site (Class 3 – individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	119	135	↑ 1	↑ 1%
	After	120	135		
	Upstream	115	132	↓ 4	↓ 3%
	Downstream	117	134	↓ 2	↓ 2%
SUN	Before	118	133	↑ 2	↑ 2%
	After	121	136		
	Upstream	115	132	↓ 3	↓ 3%
	Downstream	118	136	↑ 0	↑ 0%
Mon	Before	120	135	↓ 1	↓ 1%
	After	120	134		
	Upstream	116	133	↓ 5	↓ 4%
	Downstream	118	134	↓ 2	↓ 2%

Changes in 85th percentile speed.

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.7 at the 95 percent confidence level shows that there is a minor increase in the after 85th percentile speeds with about 1 km/hr to 3 km/hr than the 85th percentile speeds of the Before PVMS case on Saturday and Sunday days while there is a reduction of 1km/hr on Monday after installing PVMS.

Change in Proportions of Speeding Vehicles

Figures F.3 illustrates the frequencies of the observed speeds for Class 3 grouped in 10km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds in work zones when the PVMS sign was installed. It's noticeable that high speeds observations for speed range 120 to more than 160 km/hr is increased after installing the PVMS. The vehicles of Class 3 with speed range of more than 60 to 100 is reduced after installing the PVMS.

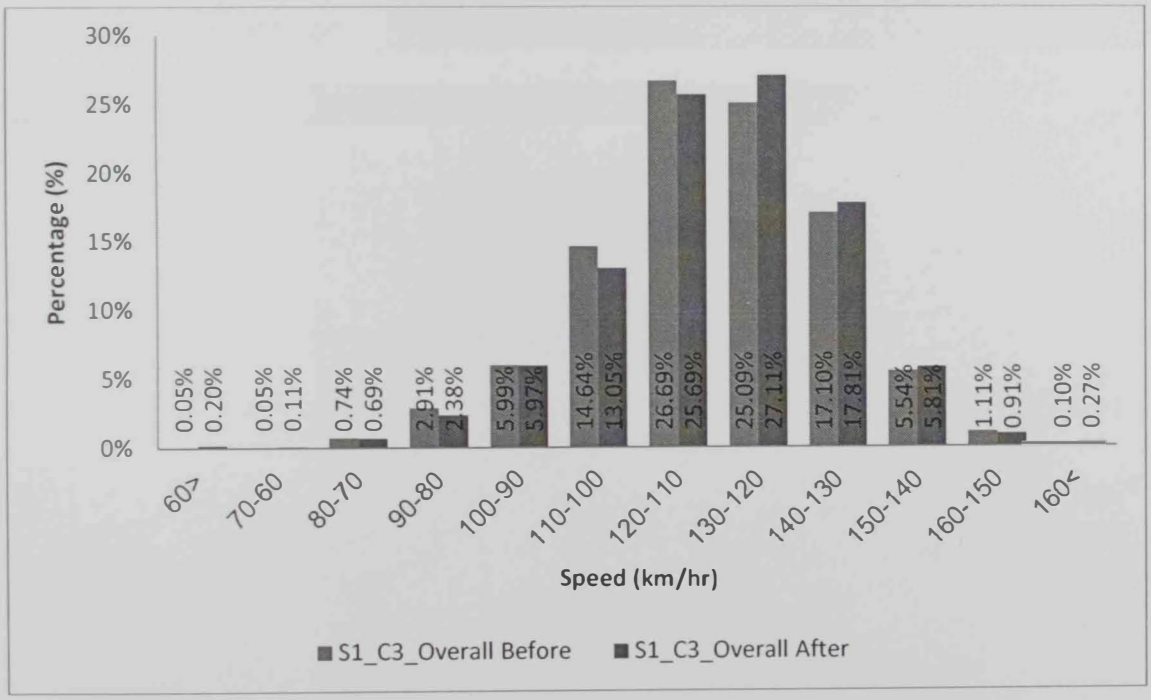


Figure F.3: Percentages of High Speeds for E11 Road (Work Zone) for Class 3

Table F.8 shows the percentages of higher-speed Class3 vehicle's exceeding the speed limit. The overall figures show that about 91% of the Class 3 vehicles are not complying with the speed limit.

Table F.8: Percentages of High Speeds at Work zone for Class 3

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	16%	26%	24%	16%	8%
	After	16%	23%	27%	17%	8%
	Upstream	18%	23%	23%	12%	6%
	Downstream	18%	21%	19%	13%	6%
SUN	Before	15%	29%	23%	16%	6%
	After	11%	25%	26%	20%	8%
	Upstream	20%	26%	21%	11%	7%
	Downstream	15%	23%	21%	16%	11%
Mon	Before	12%	26%	28%	20%	6%
	After	12%	28%	29%	17%	6%
	Upstream	23%	24%	20%	10%	6%
	Downstream	14%	26%	23%	16%	7%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speeds

2 sample t-test: Speed Means for Before and After PVMS

As shown in Table F.9 the results indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS when p-value is > 0.005. Negative t-values indicate that speed means for the Before PVMS case is less than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

The upstream t-value and p-values indicate that there is no statistical significant difference between the upstream and downstream speed means of the After case with the Before case. The positive t-value indicate that speed means for the Before case is less than the speed means for the upstream and downstream of the After PMVS case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (80km/hr)

As shown in Table F.9, there is no statistical difference between the Before PVMS cases with the speed limit where p-value is greater than 0.005. The positive t-values indicates that speed means for the Before and After PVMS cases are greater than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (140km/hr):

p-values indicate that there is no statistical significant difference of the speed means with the speed limit. t-values indicate that the upstream and downstream speed means are greater than the speed limit.

Table F.9: t-Test results for Work zone (Class 3 – individual days)

Site 1 – Class 3	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	-1.13	-4.14	1.22
	p-value	0.129	0	0.888
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	6.37	5.83	8.27
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	2.9	-0.12	4.05
	p-value	0.998	0.452	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	93.91	94.26	107.05
	p-value	1	1	1
1 sample t-test: Speed Means for After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	103.95	100.55	107.08
	p-value	1	1	1
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	84.15	81.49	89.97
	p-value	1	1	1
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	70.88	70.66	76.16
	p-value	1	1	1

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

E10 at Al Raha Beach Area

i. Comparison of Before and After for Class 1 – Individual days

In this comparison, Vehicles of Class 1 were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table F.10 shows the average speed at E10 road for both before and after PVMS cases during the data collection period. There were minor changes of ±1% in average speed after installing PVMS. The average speed for both Before PVMS and After PVMS is less than the speed limit 140 km/hr (Posted speed is 120km.hr including margin of 20km/hr). The average speed for both cases is less than the speed limit with about 10km/hr.

The average speed for the upstream and downstream after PVMS case are reduced about 8% and 4% prospectively comparing to the Before PVMS average speed on weekdays (Sunday and Monday) and it has minor changes during Saturday with about ±1%.

Changes in 85th percentile speed.

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.10 shows the 85th percentile comparison between the before and after cases. As shown in Table F.10 at there is minor reduction about 1km/hr to 2km/hr in 85th percentile speeds when PVMS installed.

Table F.10: MOE's results for E10 road at Al Raha Beach (Class 1 – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	129	148	↑ 0	↑ 0%
	After	130	147		
	Upstream	130	137	↑ 1	↑ 0%
	Downstream	129	132	↓ 0	↓ 0%
SUN	Before	129	149	↑ 0	↑ 0%
	After	129	147		
	Upstream	118	138	↓ 11	↓ 8%
	Downstream	118	133	↓ 11	↓ 8%
Mon	Before	119	149	↓ 0	↓ 0%
	After	119	148		
	Upstream	114	138	↓ 5	↓ 4%
	Downstream	114	133	↓ 5	↓ 4%

Change in Proportions of Speeding Vehicles

The speed distribution is analysed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figure F.4 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds at E10 Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced after installing the PVMS. The reduction is about 2.38% for the 140km/hr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 140 km/hr are slightly increased after installing the PVMS. These observations are similar to the All Classes case.

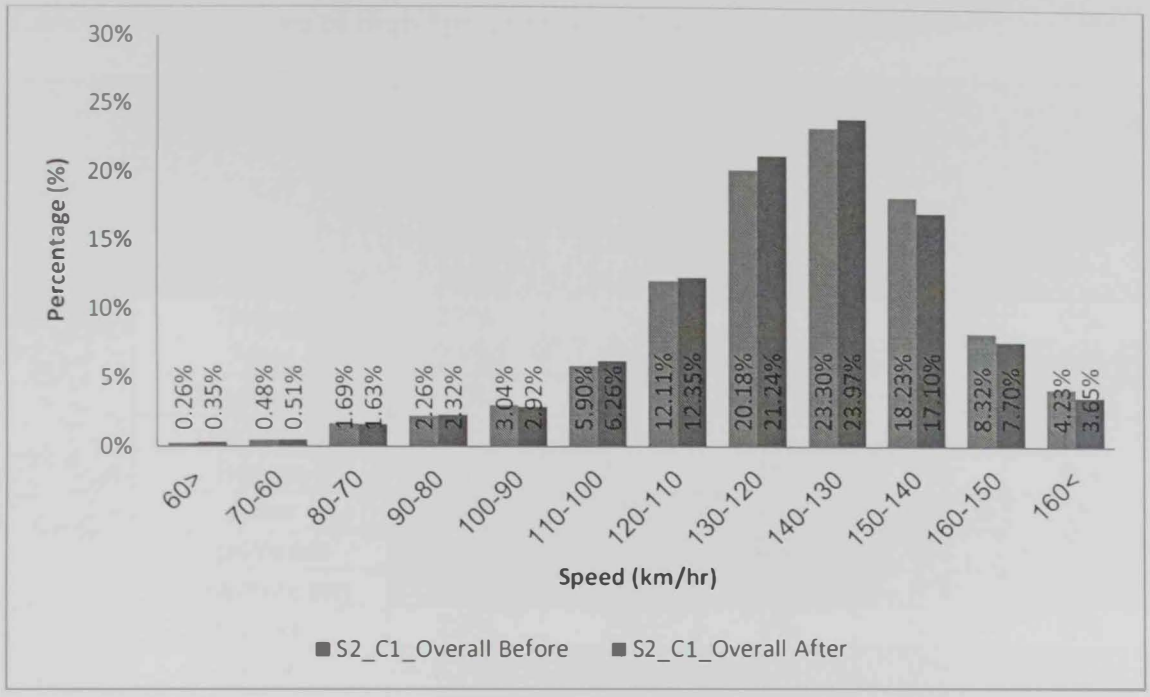


Figure F.4: Percentages of High Speeds for E10 Road for Class 1

Table F.11 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 29% of Class 1 vehicles are not complying with the speed limit in both cases Before PVMS and After PVMS. The difference between the percentage of vehicles exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

In general, vehicles exceeding the speed limit are reduced after installing the PVMS by about 1% to 2%. Also, the vehicles exceeding the speed limit at the upstream and downstream after PVMS locations are less than the Before PVMS.

Table F.11: Percentages of High Speeds for E10 Road for Class 1

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	22%	6%	1%	0%	0%
	After	21%	6%	1%	0%	0%
	Upstream	8%	2%	0%	0%	0%
	Downstream	5%	1%	0%	0%	0%
SUN	Before	23%	7%	1%	0%	0%
	After	21%	6%	1%	0%	0%
	Upstream	10%	2%	0%	0%	0%
	Downstream	6%	1%	0%	0%	0%
Mon	Before	22%	7%	1%	0%	0%
	After	21%	7%	1%	0%	0%
	Upstream	10%	2%	0%	0%	0%
	Downstream	6%	1%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speed:

2 sample t-test: Speed Means for Before and After PVMS:

The results as shown in Table F.12 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS:

For both cases Upstream and Downstream After PVMS, t-value and p-values indicate that there is no statistical significant difference between the upstream speed means of the After case and the Before case and Speed means for the upstream and downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (140km/hr):

As shown in Table F.12, there is a statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is less than 0.005. The negative t-values indicates that speed means for the Before and After PVMS cases are less than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (140km/hr):

There is a statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is less than 0.005. The negative t-values indicate that speed means for the Upstream and Downstream After PVMS are less than the speed limit.

Table F.12: t-Test results for E10 Road at Al Raha Beach (Class 1 – individual days)

Site 2 – Class 1	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	2.41	6.53	6.34
	p-value	0.992	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	74.11	76.59	75.93
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	104	106.73	109.78
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	-93.71	-92.13	-90.95
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	-96.31	-102.6	-99.58
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-220.69	-223.34	-216.24
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (140km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-274.13	-278.07	-279.07
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

ii. Comparison of Before and After for Class 2 – Individual days

In this comparison, Vehicles of Class 2 were considered for each day and compared based on the collected speed data for each individual day. The MOE's results were detailed as follows:

Average Speed

Table F.13 shows the average speed at E10 road for both before and after PVMS cases during the data collection period. There was minor reduction of 1% in average speed after installing PVMS. The average speed for both Before PVMS and After PVMS is less than

the speed limit 140 km/hr (Posted speed is 120km.hr including margin of 20km/hr). The average speed for both cases is less than the speed limit with about 22km/hr.

The average speed for the upstream and downstream after PVMS case are reduced about 20% and 27% prospectively comparing to the Before PVMS average speed during the speed survey period.

Changes in 85th percentile speed.

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.13 shows the 85th percentile comparison between the before and after cases. As shown in Table F.13 at there is minor reduction about 1km/hr in 85th percentile speeds when PVMS installed.

Table F.13: MOE's results for E10 road at Al Raha Beach (Class 2 – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	119	145	↓ 1	↓ 1%
	After	118	144		
	Upstream	96	119	↓ 23	↓ 19%
	Downstream	87	104	↓ 32	↓ 27%
SUN	Before	119	146	↓ 1	↓ 1%
	After	118	145		
	Upstream	96	120	↓ 24	↓ 20%
	Downstream	88	107	↓ 31	↓ 26%
Mon	Before	119	146	↓ 1	↓ 1%
	After	118	144		
	Upstream	96	119	↓ 24	↓ 20%
	Downstream	87	105	↓ 31	↓ 27%

Change in Proportions of Speeding Vehicles

The speed distribution is analysed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figures F.5 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The Figure shows a general trend of relatively high speeds at E10 Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced after installing the PVMS. The reduction is about 2.38% for the 140km/hr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 140 km/hr are slightly increased after installing the PVMS.

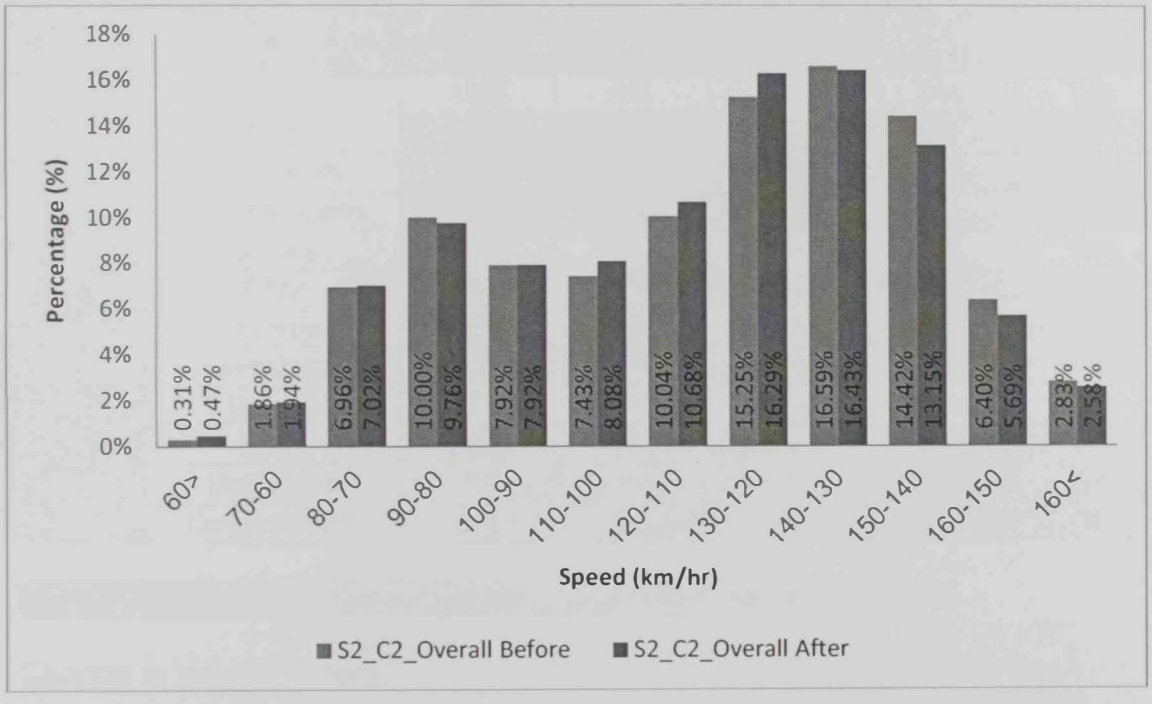


Figure F.5: Percentages of High Speeds for E10 Road for Class 2

Table F.14 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 23% of the Class 2 vehicles are not complying with the speed limit in both cases Before PVMS and After PVMS. The difference between the

percentage of vehicles exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

In general, vehicles exceeding the speed limit are reduced after installing the PVMS by about 1% to 2%. Also, the vehicles exceeding the speed limit at the upstream and downstream after PVMS locations are less than the Before PVMS.

Table F.14: Percentages of High Speeds for E10 Road for Class 2

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	18%	4%	1%	0%	0%
	After	17%	4%	1%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%
SUN	Before	19%	5%	1%	0%	0%
	After	16%	4%	1%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	2%	0%	0%	0%	0%
Mon	Before	17%	5%	1%	0%	0%
	After	16%	4%	1%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speed:

2 sample t-test: Speed Means for Before and After PVMS:

The results as shown in Table F.15 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS:

For both cases Upstream and Downstream After PVMS, t-value and p-values indicate that there is no statistical significant difference between the upstream speed means of the After case and the Before case and Speed means for the upstream and downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (140km/hr):

As shown in Table F.15, there is a statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is less than 0.005. The negative t-values indicates that speed means for the Before and After PVMS cases are less than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (140km/hr):

There is a statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is less than 0.005. The negative t-values indicate that speed means for the Upstream and Downstream After PVMS are less than the speed limit.

Table F.15: t-Test results for E10 Road at Al Raha Beach (Class 2 – individual days)

Site 2 – Class 3	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	2.15	2.57	2.83
	p-value	0.984	0.995	0.998
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	55.16	55.73	56.3
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	78.7	75.61	78.15
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	-86.69	-80.3	-79.82
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	-86.87	-85.51	-86.74
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-136.3	-129.93	-135.73
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-173.55	-159.12	-167.8
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

iii. Comparison of Before and After for Class 3 – Individual days

In this comparison, Vehicles of Class 3 were considered for each day and compared based on the collected speed data for each individual day. The MOE's results were detailed as follows:

Average Speed

Table F.16 shows the average speed at E10 road for both before and after PVMS cases during the data collection period. There was minor reduction of 1% to 4% in average speed after installing PVMS on Saturday and Sunday days while it's increasing by 1% on Monday. The average speed for both Before PVMS and After PVMS is more than the

speed limit 80 km/hr. The average speed for both cases is greater than the speed limit by about 25 km/hr.

The average speed for the upstream and downstream after PVMS case are reduced about 11% to 15% and 7% to 19% prospectively comparing to the Before PVMS average speed during the speed survey period.

Changes in 85th percentile speed.

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.16 shows the 85th percentile comparison between the before and after cases. As shown in Table F.16 at there is minor reduction about 4km/hr in 85th percentile speeds when PVMS installed on Sunday.

Table F.16: MOE's results for E10 road at Al Raha Beach (Class 3 – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	103	135	↓ 4	↓ 4%
	After	99	131		
	Upstream	91	113	↓ 12	↓ 11%
	Downstream	95	112	↓ 8	↓ 7%
SUN	Before	108	137	↓ 1	↓ 1%
	After	107	137		
	Upstream	91	121	↓ 16	↓ 15%
	Downstream	88	119	↓ 20	↓ 19%
Mon	Before	107	136	↑ 1	↑ 1%
	After	107	137		
	Upstream	97	119	↓ 10	↓ 10%
	Downstream	94	118	↓ 14	↓ 12%

Change in Proportions of Speeding Vehicles

The speed distribution is analysed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figure F.6 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The Figure shows a general trend of relatively high speeds at E10 Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced after installing the PVMS. The reduction is about 2.66% for the 110km/hr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 110 km/hr are slightly increased after installing the PVMS.

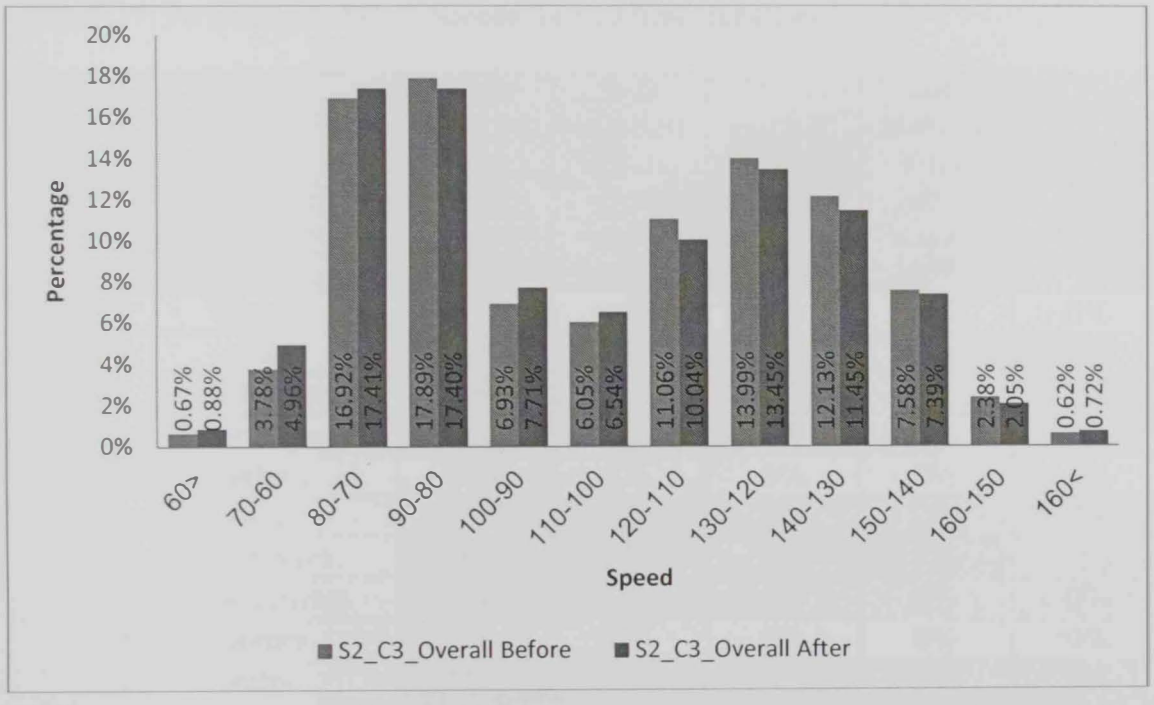


Figure F.6: Percentages of High Speeds for E10 Road for Class 3

Table F.17 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 9% of the Class 3 vehicles are not complying with the speed limit in both cases Before PVMS and After PVMS. The difference between the percentage of vehicles exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

In general, vehicles exceeding the speed limit are varying after installing the PVMS by about ±1% to ±2%. Also, the vehicles exceeding the speed limit at the upstream and downstream after PVMS locations are less than the Before PVMS.

Table F.17: Percentages of High Speeds for E10 Road for Class 3

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	8%	1%	0%	0%	0%
	After	5%	1%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%
SUN	Before	10%	1%	0%	0%	0%
	After	10%	1%	0%	0%	0%
	Upstream	3%	0%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%
Mon	Before	9%	2%	0%	0%	0%
	After	11%	2%	0%	0%	0%
	Upstream	2%	0%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speed:

2 sample t-test: Speed Means for Before and After PVMS:

The results as shown in Table F.18 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case. On Monday the speed mean of After case is greater than the speed mean of the Before case since t-value is negative.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS:

For both cases Upstream and Downstream After PVMS, t-value and p-values indicate that there is no statistical significant difference between the upstream speed means of the After case and the Before case and Speed means for the upstream and downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (80km/hr):

As shown in Table F.18, there is a statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is < 0.005. The t-values indicates that speed means for the Before and After PVMS cases are greater than the speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (80km/hr):

There is a statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is < 0.005. The t-values indicate that speed means for the Upstream and Downstream After PVMS are greater than the speed limit.

Table0 F.18: t-Test results for E10 Road at Al Raha Beach (Class 3 – individual days)

Site 2 – Class 3	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	4.27	1	-0.67
	p-value	1	0.841	0.252
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	14.85	15.14	15.66
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	18.87	18.36	17.85
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	35.17	50.07	47.99
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	33.07	46.65	47.9
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	24.94	35.14	33.02
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	16.07	30.05	28.06
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

Eastern Ring Road

i. Comparison of Before and After for Class 1 – Individual days

In this comparison, Vehicles of Class 1 were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table F.19 shows the average speed at E10 road for both before and after PVMS cases during the data collection period. There was minor reduction of 1% in average speed after installing PVMS. The average speed for both Before PVMS and After PVMS is less than the speed limit 120 km/hr (Posted speed is 100km.hr including margin of 20km/hr). The average speed for both cases is less than the speed limit with about 25km/hr.

The average speed for the upstream after PVMS case are increased about 3% to 4% comparing to the Before PVMS average speed. The downstream after PVMS case is reduced by about 2% to 3% comparing to the Before PVMS average speed.

Changes in 85^{th} percentile Speed

The 85^{th} percentile speed is the speed at which it is expected to be close to the speed limit. Table F.19 shows the 85^{th} percentile comparison between the before and after cases. There is minor reduction about 1km/hr to 2km/hr of the 85^{th} percentile speeds when PVMS is installed.

Table F.19: MOE's results for Eastern Ring Road (Class I – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	96	109	↓ 1	↓ 1%
	After	95	108		
	Upstream	99	112	↑ 3	↑ 3%
	Downstream	93	106	↓ 2	↓ 3%
SUN	Before	94	108	↓ 1	↓ 2%
	After	93	106		
	Upstream	98	112	↑ 4	↑ 4%
	Downstream	91	105	↓ 3	↓ 3%
Mon	Before	94	107	↓ 1	↓ 1%
	After	93	106		
	Upstream	98	111	↑ 3	↑ 4%
	Downstream	91	105	↓ 2	↓ 3%

Change in Proportions of Speeding Vehicles

The speed distribution is analyzed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figures F.7 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds at Eastern Ring Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced significantly after installing the PVMS. The reduction is about 4.22% for the 100km/gr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 100 km/hr are slightly increased after installing the PVMS.

Table F.20 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 2% of the vehicles are not complying with the speed limit in both cases Before PVMS and After PVMS. The difference between the

percentage of vehicles exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

In general, vehicles exceeding the speed limit are reduced after installing the PVMS by about 1% to 2%. The vehicles exceeding the speed limit at the upstream are more than the Before PVMS case. On other hand, the vehicles exceeding the speed limit at the downstream after PVMS are less than the Before PVMS.

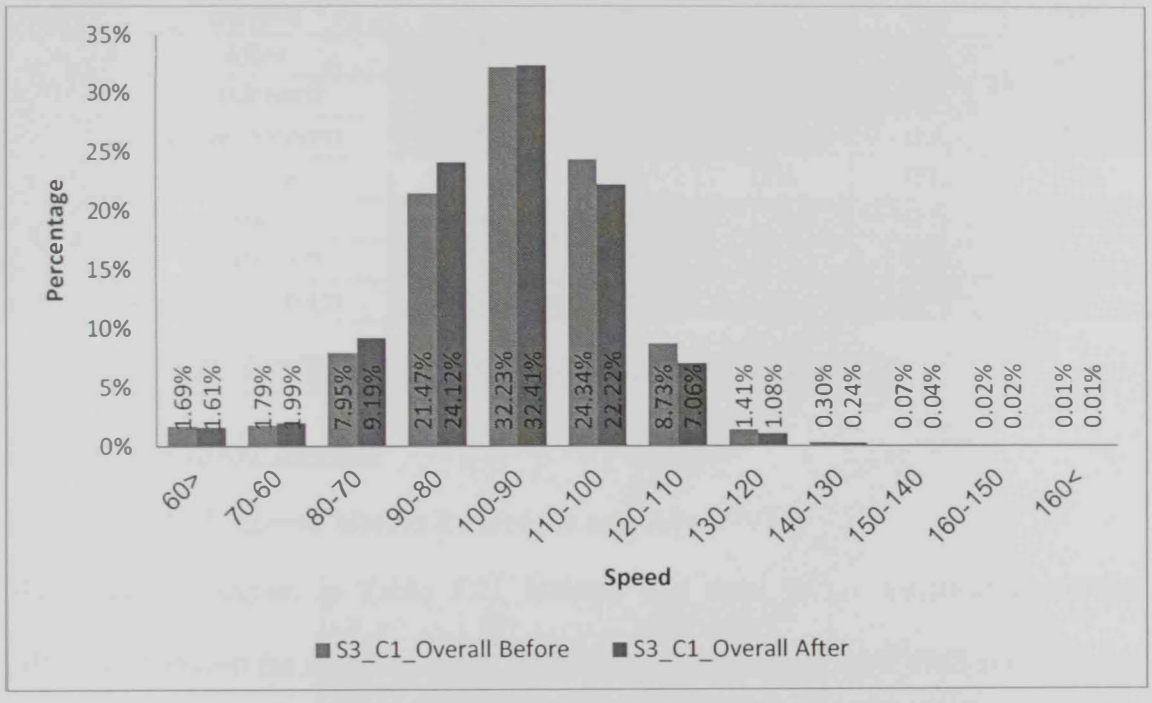


Figure F.7: Percentages of High Speeds for Eastern Ring Road for Class 1

Table F.20: Percentages of High Speeds for Eastern Ring Road for Class 1

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	2%	0%	0%	0%	0%
	After	2%	0%	0%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	2%	0%	0%	0%	0%
SUN	Before	1%	0%	0%	0%	0%
	After	1%	0%	0%	0%	0%
	Upstream	4%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%
Mon	Before	1%	0%	0%	0%	0%
	After	1%	0%	0%	0%	0%
	Upstream	3%	1%	0%	0%	0%
	Downstream	1%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speeds

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table F.21 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

The Upstream After PVMS mean speed compared with the Before PVMS, there is statistical significant difference between the speed means of Before PVMS with the Upstream After PVMS since p-value is < 0.005. Negative t-values indicate that the speed means for the Before PVMS case is less than the speed means for the After PVMS case.

For the case of Downstream After PVMS compared with the Before PVMS, t-value and p-values indicate that there is no statistical significant difference and Speed means for the Downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (120km/hr):

As shown in Table F.21, there is a statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is less than 0.005. The negative t-values indicates that speed means for the Before and After PVMS cases are less than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (120km/hr):

There is a statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is less than 0.005. The negative t-values indicate that speed means for the Upstream and Downstream After PVMS are less than the speed limit.

Table F.21: t-Test results for Eastern Ring Road (Class 1 – individual days)

Site 3 – Class 1	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	6.31	16.35	15.9
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	-34.56	-42.19	-39.8
	p-value	0	0	0
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	26.4	33.77	35.52
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	-364.39	-395.6	-423.08
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	-393.33	-455.25	-454.58
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-309.88	-354.66	-362.1
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-435.77	-498.63	-503.92
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

ii. Comparison of Before and After for Class 2 – Individual days

In this comparison, Vehicles of Class 2 were considered for each day and compared based on the collected speed data for each individual day. The results were detailed as follows:

Average Speed

Table F.22 shows the average speed at Eastern Ring Road for both before and after PVMS cases during the data collection period. There was minor reduction of 1% to 2% in average speed after installing PVMS. The average speed for both Before PVMS and After PVMS is less than the speed limit 120 km/hr (Posted speed is 100km.hr including

margin of 20km/hr). The average speed for both cases is less than the speed limit with about 38km/hr.

The average speed for the upstream and downstream after PVMS case are reduced about 1% and 4% to 5% prospectively comparing to the Before PVMS average speed during the speed survey period.

Changes in 85th percentile Speed

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.22 shows the 85th percentile comparison between the before and after cases. As shown in Table F.22 at there is minor reduction about 1km/hr to 3km/hr in 85th percentile speeds when PVMS installed.

Table F.22: MOE's results for Eastern Ring Road (Class 2 – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	83	98	↓ 1	↓ 1%
	After	82	95		
	Upstream	82	96	↓ 0	↓ 0%
	Downstream	79	91	↓ 4	↓ 4%
SUN	Before	83	97	↓ 2	↓ 2%
	After	81	95		
	Upstream	82	97	↓ 0	↓ 1%
	Downstream	78	91	↓ 5	↓ 5%
Mon	Before	82	96	↓ 2	↓ 2%
	After	81	95		
	Upstream	83	96	↑ 0	↑ 0%
	Downstream	78	90	↓ 3	↓ 5%

Change in Proportions of Speeding Vehicles

The speed distribution is analyzed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figures F.8 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The Figure shows a general trend of relatively high speeds at Eastern Ring Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced after installing the PVMS. The reduction is about 3% for the 90km/hr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 90 km/hr are slightly increased after installing the PVMS.

Table F.23 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that about 1% of the Class 2 vehicles are not complying with the speed limit in both cases Before PVMS and After PVMS. The difference between the percentage of vehicles exceeding speed limits for the After PVMS case is compared with the percentage of the vehicles exceeding speed limit for the before PVMS case.

In general, vehicles exceeding the speed limit are reduced after installing the PVMS by about 1%. Also, the vehicles exceeding the speed limit at the upstream after PVMS locations are greater than the Before PVMS by about 1% while the vehicles exceeding the speed limit at the downstream after PVMS locations are less than the Before PVMS.

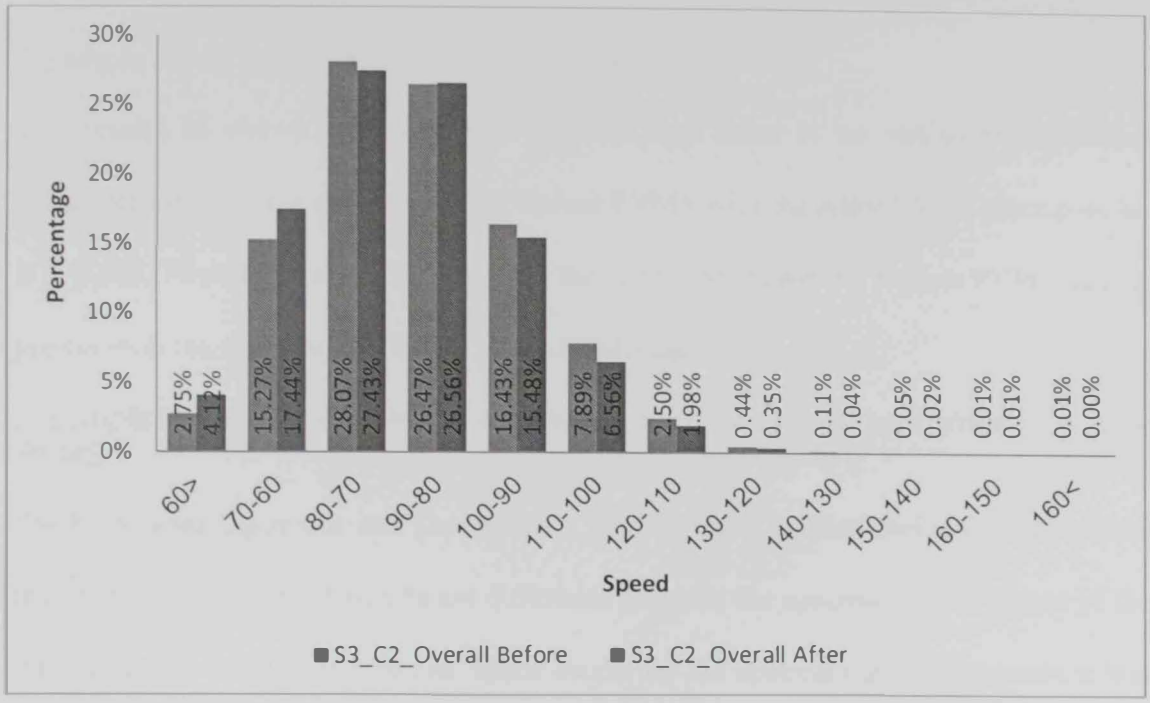


Figure F.8: Percentages of High Speeds for Eastern Ring Road for Class 2

Table F.23: Percentages of High Speeds for Eastern Ring Road for Class 2

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	1%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%
SUN	Before	1%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%
Mon	Before	0%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speeds

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table F.24 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS

For both cases Upstream and Downstream After PVMS, t-value and p-values indicate that there is no statistical significant difference between the upstream speed means of the After case and the Before case and Speed means for the upstream and downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (120km/hr:

As shown in Table F.24, there is a statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is less than 0.005. The negative t-values indicates that speed means for the Before and After PVMS cases are less than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (120km/hr)

There is a statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is less than 0.005. The negative t-values indicate that speed means for the Upstream and Downstream After PVMS are less than the speed limit.

Table F.24: t-Test results for Eastern Ring Road (Class 2 – individual days)

Site 3 – Class 2	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	3.86	6.1	5.14
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	0.44	0.75	0.44
	p-value	0.671	0.774	0.67
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	12.57	15.29	14.99
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	-177.6	-173.02	-184.91
	p-value	0	0	0
1 sample t-test: Speed Means for After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	-191.71	-182.64	-183.2
	p-value	0	0	0
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	-168.35	-162.87	-166.45
	p-value	0	0	0
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (120km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	-216.25	-202.21	-203.54
	p-value	0	0	0

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

iii. Comparison of Before and After for Class 3 – Individual days

In this comparison, Vehicles of Class 3 were considered for each day and compared based on the collected speed data for each individual day. The MOE's results were detailed as follows:

Average Speed

Table F.25 shows the average speed at Eastern Ring Road for both before and after PVMS cases during the data collection period. There was minor reduction of 1% to 2% in

average speed after installing PVMS. The average speed for both Before PVMS and After PVMS is more than the speed limit 80 km/hr by about 10 km/hr.

The average speed for the upstream after PVMS case are increased about 1% to 2% comparing to the Before PVMS average speed. The downstream after PVMS case is reduced by about 2% to 6% comparing to the Before PVMS average speed.

Table F.25: MOE's results for Eastern Ring Road (Class 3 – Individual days)

Day	Case	Mean	85th Percentile	Mean Difference (Before – After)	% Reduction
SAT	Before	89	102	↓ 1	↓ 1%
	After	87	101		
	Upstream	88	104	↓ 0	↓ 0%
	Downstream	85	97	↓ 4	↓ 4%
SUN	Before	90	102	↓ 2	↓ 2%
	After	88	100		
	Upstream	91	105	↑ 1	↑ 2%
	Downstream	85	97	↓ 5	↓ 6%
Mon	Before	89	102	↓ 2	↓ 2%
	After	88	100		
	Upstream	90	105	↑ 1	↑ 1%
	Downstream	85	97	↓ 3	↓ 5%

Changes in 85th percentile Speed

The 85th percentile speed is the speed at which it is expected to be close to the speed limit. Table F.25 shows the 85th percentile comparison between the before and after cases. As shown in Table F.25 at there is minor reduction about 1km/hr to 2km/hr in 85th percentile speeds when PVMS installed on Sunday.

Change in Proportions of Speeding Vehicles

The speed distribution is analyzed for Before PVMS mean speeds and After PVMS mean speeds to demonstrate the effectiveness of the PVMS. Figure F.9 illustrates the frequencies of the observed speeds grouped in 10 km/hr speed intervals for the whole period of speed survey. The figure show a general trend of relatively high speeds at Eastern Ring Road when the PVMS sign was installed. It's noticeable that high speeds observations is reduced significantly after installing the PVMS. The reduction is about 6.21% for the 90km/hr to more than 160 km/hr speeds. The speeds of less than 60km/hr to 90 km/hr are slightly increased after installing the PVMS.

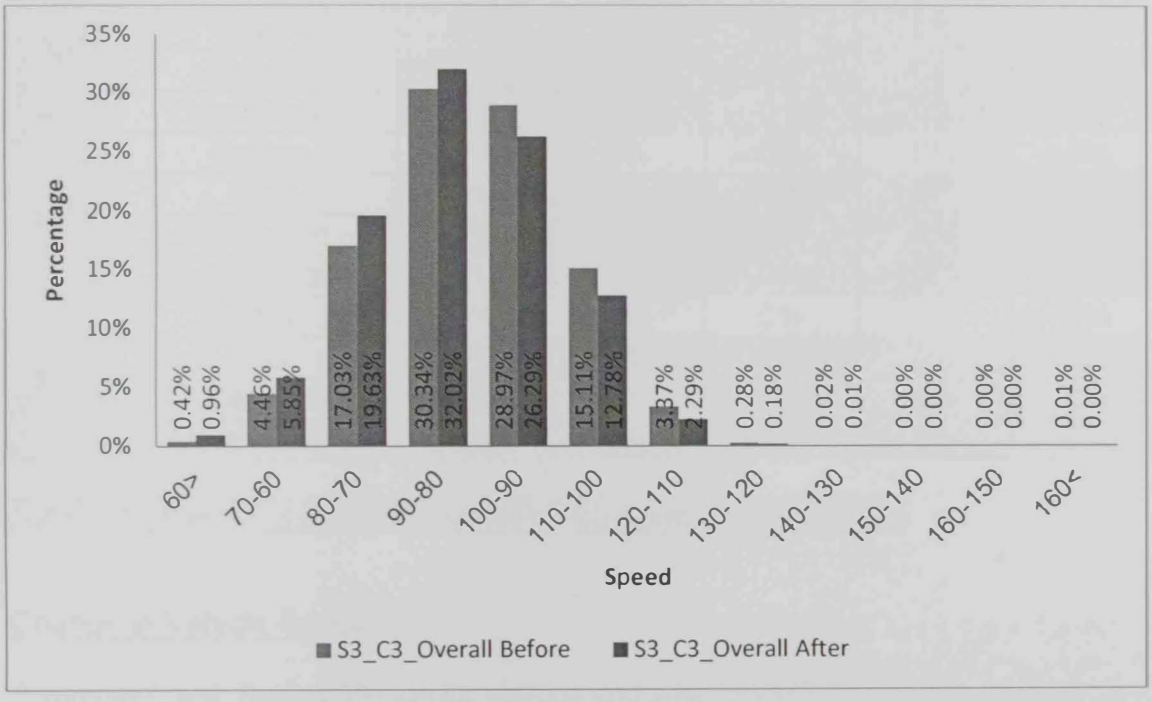


Figure F.9: Percentages of High Speeds for Eastern Ring Road for Class 3

Table F.26 shows the percentages of higher-speed vehicles exceeding the speed limit. The overall figures show that most of Class 3 vehicles are complying with the speed limit in both cases Before PVMS and After PVMS.

In general, vehicles exceeding the speed limit are reduced after installing the PVMS. The vehicles exceeding the speed limit at the upstream are more than the Before PVMS case. On other hand, the vehicles exceeding the speed limit at the downstream after PVMS are less than the Before PVMS.

Table F.26: Percentages of High Speeds for Eastern Ring Road for Class 3

Day	Case	% at least 10 km/h over speed limit	% at least 20 km/h over speed limit	% at least 30 km/h over speed limit	% at least 40 km/h over speed limit	% above 40 km/h over speed limit
SAT	Before	0%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%
SUN	Before	0%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%
Mon	Before	0%	0%	0%	0%	0%
	After	0%	0%	0%	0%	0%
	Upstream	1%	0%	0%	0%	0%
	Downstream	0%	0%	0%	0%	0%

%After < %Before	%After > %Before	%After = %Before

Change in Vehicle Speeds

2 sample t-test: Speed Means for Before and After PVMS

The results as shown in Table F.27 indicate that there is no statistical significant difference between the speed means of Before PVMS with the After PVMS since p-value is > 0.005. Positive t-values indicate that the speed means for the Before PVMS case is greater than the speed means for the After PVMS case.

2 sample t-test: Speed Means for Before and Upstream/Downstream of After PVMS:

The Upstream After PVMS mean speed compared with the Before PVMS, there is statistical significant difference between the speed means of Before PVMS with the Upstream After PVMS since p-value is < 0.005 on Sunday and Monday only. Negative t-values indicate that the speed means for the Before PVMS case is less than the speed means for the After PVMS case On Sunday and Monday.

For the case of Downstream After PVMS compared with the Before PVMS, t-value and p-values indicate that there is no statistical significant difference and Speed means for the Downstream is less than the speed means for the Before case.

1 sample t-test: Speed Means for Before/After PVMS and Speed Limit (80km/hr)

As shown in Table F.27, there is no statistical significant difference between the Before and After PVMS cases with the speed limit where p-value is more than 0.005. The t-values indicates that speed means for the Before and After PVMS cases are more than speed limit.

1 sample t-test: Speed Means for Upstream/Downstream PVMS and Speed Limit (80km/hr):

There is no statistical significant difference between the Upstream and Downstream After PVMS case with the speed limit where p-value is more than 0.005. The t-values indicate that speed means for the Upstream and Downstream After PVMS are greater than the speed limit.

Table F.27: t-Test results for Eastern Ring Road (Class 3 – individual days)

Site 3 – Class 3	Result	SAT	SUN	MON
2 sample t-test: Speed Means for Before and After PVMS: Null Hypothesis H_o: $\mu_b-\mu_a \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_a < 0$	t-value	3.83	8.9	6.26
	p-value	1	1	1
2 sample t-test: Speed Means for Before and Upstream of After PVMS: Null Hypothesis H_o:$\mu_b-\mu_u \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_u<0$	t-value	0.89	-4.92	-2.98
	p-value	0.812	0	0.001
2 sample t-test: Speed Means for Before and Downstream After PVMS: Null Hypothesis H_o:$\mu_b-\mu_d \geq 0$ Alternative Hypothesis H_a: $\mu_b-\mu_d<0$	t-value	11.76	20.42	19.52
	p-value	1	1	1
1 sample t-test: Speed Means for Before PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_b \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_b>$ Posted Speed Limit	t-value	34.41	57.38	56.07
	p-value	1	1	1
1 sample t-test: Speed Means for After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_a \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_a>$ Posted Speed Limit	t-value	30.61	43.73	44.8
	p-value	1	1	1
1 sample t-test: Speed Means for Upstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu u \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_u>$ Posted Speed Limit	t-value	28.1	51.06	45.78
	p-value	1	1	1
1 sample t-test: Speed Means for Downstream After PVMS and Speed Limit (80km/hr) Null Hypothesis H_o:$\mu_d \leq$ Posted Speed Limit Alternative Hypothesis H_a: $\mu_d>$ Posted Speed Limit	t-value	20.05	27.41	25.9
	p-value	1	1	1

μ_B: Mean Speed Before PVMS
μ_a: Mean Speed After PVMS
μ_u: Upstream Mean Speed After PVMS
μ_d: Downstream Mean Speed After PVMS

بالإضافة إلى ذلك، فإن استبيان العاملين في مواقع الإنشاءات على الطرق كان لهم آراء متعدده حيث اظهرت نتائج الاستبيان بأن شريحة كبيرة من العاملين هم على دراية كافية في اللوحات الالكترونية المتنقلة واعتبروها أفضل الوسائل المستخدمة لتأمين السلامة المرورية خلال مواقع الانشاءات. وقد بيّن معظم العاملين الذين شملهم الاستبيان بأنهم يشعرون بأمان أكثر في وجود تلك اللوحات ضمن مواقع الانشاءات وخاصة خلال العمل الليلي. وقد كانت أغلب الملاحظات حول اللوحات بأنها غير شائعة الاستخدام في مواقع العمل ويجب تطبيقها فوراً في مواقع الانشاءات الحالية في مدينة أبوظبي وكذلك يجب مراعاة التشغيل خلال مرحلة العمل منذ بدايتها لنهايتها وعدم إزالتها لحين الانتهاء من العمل. بالإضافة لذلك فإنه يجب التركيز على زيادة وعي الجمهور حول أهميتها كوسيلة شائعة تستخدم ضمن مواقع الانشاءات.

خلصت الدراسة في النهاية إلى بعض التوصيات ومن أهمها:

- التركيز والاهتمام أكثر بعملية التشغيل والصيانة للوحات الالكترونية المتنقلة سواء التابعة لدائرة النقل أو وزارة الداخلية – شرطة أبوظبي.

- يجب تحديث الرسائل المعروضة باستمرار مع عرض رسائل تنبيهية وتحذيرية لموضوعات عدة من شأنها التقليل من الحوادث المرورية.

- بشكل عام، من الممكن عرض الرسائل على اللوحات الالكترونية المتنقلة على شكل صور أو أشكال لمخاطبة جميع شرائح مستخدمي الطريق ومن ضمنها مستخدمي الطريق الأميين الغير قادرين على القراءة سواء اللغة العربية أو الإنجليزية المستخدمة في الرسائل المعروضة.

من خلال المنهج المتبع في التحليل الوصفي والتحليلي المستخدم في هذه الدراسة، تُظهر النتائج الخاصة بمعدل السرعات قبل وبعد تركيب اللوحات الالكترونية المتنقلة في المواقع الثلاث المذكورة سابقا بعدم وجود فروقات ملحوظه من خلال احتساب الفرق في معدل السرعات والمنين الخامس والثمانين. وتظهر النتائج انخفاض طفيف ذا دلالة غير احصائية في السرعات بعد تركيب اللوحات الالكترونية على الشوارع المارة خلال المناطق الريفية والحضرية. وتخلص النتائج إلى أن اللوحات الالكترونية المتنقلة ليست فعّاله وذات دلالة غير احصائية عند تطبيق اختبارات التغير في معدلات السرعة حيث أن القيمة الفعّالة أكبر من 0.005 عند مستوى الثقة 95%. وقيمة الانخفاض في معدلات السرعة حوالي 1% على الطرق الرئيسية والفرعية المارة في المناطق الريفية والحضرية.

في حين أن اللوحات غير فعّاله لتخفيض معدلات السرعة في مواقع الانشاءات على الطرق. حيث أن تركيب اللوحات الالكترونية المتنقلة حديثا في مواقع الانشاءات تسببت في ارباك للسائقين خاصة بوجود إشارات مرورية ثابتة تشير إلى انخفاض السرعا المحددة تدريجيا على جزء قصير من الشارع. وإلحاقا لذلك فإن نسبة المركبات ذات السرعات العالية (سرعة المركبات أعلى من السرعة المحددة) انخفض بشكل طفيف بعد تركيب اللوحات الالكترونية المتنقلة على الشوارع.

أما بالنسبة للاستبيان الخاص بالسائقين، فقد لوحظ بأن شريحة كبيرة من مستخدمي الطرق الذي شملهم الاستبيان أشاد باللوحات الالكترونية المتنقلة ومدى أهميتها وفائدتها كوسيلة ارشادية للسائقين عن طريق عرضها للمعلومات المرورية الهادفة وأهمها تحسين السلامة المرورية خلال مواقع الانشاءات على الطرق. وقد أبدى مستخدمي الطريق من خلال الاستبيان بأن اللوحات الالكترونية المتنقلة فعّاله في تنبيه السائقين للحالات المرورية الغير اعتيادية كوقوع حوادث مرورية على طريق ما أو وضعها لتوجيه السائقين خلال القيادة على طرق تحوي مواقع انشاءات. وقد طرح الكثير من الملاحظات من خلال الاستبيان حول آلية تشغيل اللوحات المرورية من حيث تحديث الرسائل المعروضه وتغييرها باستمرار حسب حالة الطريق وعدم إهمالها ولتشمل فوائد عدة غير المعروضه باستمرار حيث أن هذه الوسيلة تعتبر مهمة في التواصل مع مستخدمي الطرق وليس فقط سائقين المركبات لتزداد ثقة الجمهور في هذه الوسيلة وبيان أهميتها.

مـلـخـــص

في مارس عام 2008، وقع حادث مروري نتيجة لتصادم هائل بين 60 مركبة في منطقة غنتوت على شارع أبوظبي/دبي أسفر عن وفاة ثلاثة أشخاص وجرح مايقارب 350 شخص. الضباب وانعدام الرؤوية خلال ساعات الصباح الباكر كان السبب الرئيسي في وقوع الحادث. ونتيجة لزيادة أعداد الحوادث على شوارع أبوظبي قامت دائرة النقل بتركيب مايقارب 40 لوحة الكترونية متنقلة على شوارع أبوظبي الداخلية والخارجية كأحد الحلول المقترحة في التحكم في طيش القيادة على الطرقات وتحسين السلامة المرورية. تهدف تلك اللوحات الالكترونية المتنقلة إلى التواصل مع مستخدمي الطريق وتنبيه السائقين وتحذيرهم في الأحوال الجوية الطارئة (الضباب، الغبار،المطر..إلخ). بالإضافة لذلك تستخدم هذه اللوحات بهدف تقليل فرص وقوع الحوادث المرورية في المناطق الخطرة كمواقع الإنشاءات على الطرق، وعبور المشاة بالقرب من المدارس وخلال الأحداث الهامة لتنبيه مستخدمي الطرق بأوقاتها وأماكنها.

تهدف هذه الدراسة إلى تقييم اللوحات الالكترونية في تأثيرها على تحسين السلامة المرورية والأخذ بآراء الجمهور ومستخدمي الطرق حول أهمية اللوحات الالكترونية المتنقلة وملاحظاتهم حول عملها ومدى فائدتها. يشار إلى أنه لم يتم تقييم هذه اللوحات في مدينة أبوظبي إلى الآن لهذا اعتمدت الدراسة منهجية طويلة الأمد لتشمل جمع المعلومات الخاصة بالمركبات كالسرعة وكثافة المركبات وتصنيفها في ثلاث أماكن من أجزاء طرق رئيسية لمرحلتين قبل وضع وتشغيل اللوحات الالكترونية المتنقلة وبعد وضعها وتشغيلها. وتشمل أجزاء الطرق الرئيسية ثلاث مواقع وهي:

- شارع رئيسي (E11) يمر خلال موقع انشاءات ذا سرعه محدده 100 كم/س.
- شارع رئيسي (E10) يمر خلال منطقة ريفية ذا سرعة محدده 140 كم/س.
- شارع رئيسي (الدائري الشرقي) متفرع يمر خلال منطقة حضرية ذا سرعة محدده 120 كم/س.

بالإضافة إلى ذلك، تم أخذ آراء الجمهور ومستخدمي الطرق والعاملين في مناطق الإنشاءات من خلال مقابلتهم وطرح الأسئلة حول اللوحات المرورية المتنقلة من خلال استبينا تم إعداده بلغتين عربية وإنجليزية.

UAEU College of Engineering

جامعة الإمارات العربية المتحدة
United Arab Emirates University

جامعة الإمارات العربية المتحدة
كلية الهندسة

تقييم فاعلية اللوحات المرورية الإلكترونية المتنقلة لتحسين السلامة المرورية لمستخدمي الطرق وعمّال الإنشاءات على الطرق في أبو ظبي

إعداد

خالد إسماعيل الزعبي

قسم الهندسة المدنية والبيئية

رسالة مقدمة لاستكمال متطلبات الحصول على درجة
ماجستير العلوم في الهندسة المدنية

ديسمبر 2012