NDOT Research Report

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Field Test of Slow Moving Traffic Alerting System on Freeways in Las Vegas, Nevada - Assessment of the Effectiveness of the Dynamic Message Signs on the Freeways in Las Vegas, Nevada

October 2015

Nevada Department of Transportation

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Field Test of Slow Moving Traffic Alerting System on Freeways in Las Vegas, Nevada

Assessment of the Effectiveness of the Dynamic Message Signs on the Freeways in Las Vegas, Nevada

Research Report
Submitted to

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Executive Summary

It has been perceived that the travelers do not respond to the incident messages on the dynamic message signs in the Las Vegas area in Nevada. The objective of the study is to evaluate whether dynamic message signs (DMS) in the Las Vegas freeway systems have been effective in distributing incident/traffic information. Specifically, this study investigates whether incident/traffic information can be distributed to the motorists in a timely manner: at the right time and at right location and in the right format. A literature review is conducted to see how dynamic message signs have been used effectively in other cities in the U.S. A tour to the traffic management center, the Freeway and Arterial System of Transportation (FAST) is made to observe the operations of DMSs. The performance of DMSs in providing traffic information to allow travelers to take alternative route is evaluated based on comparing the congestion progression and the activation of DMSs. A survey to travelers in the Las Vegas area is also conducted. Based on the investigations, it is concluded that (1) incident information should be provided earlier; (2) more relevant information on incident should be provided; and (3) more reliable information should be provided. Based on the conclusions, it is recommended (1) developing a computer aid system for using dynamic message signs in traffic management, (2) improving on the messages on incidents provided on DMS, (3) improving the reliability of travel time information provided on DMS, (4) improving the data system in incident management in FAST, and (5) conducting a study on locating the DMSs on the Las Vegas network.

Chapter 1 Introduction

Dynamic Message Signs (DMS) (also called Changeable Message Signs (CMS), Variable message signs (VMS), or Electronic Message Signs (EMS)), are devices installed along the roadside to display messages of special events. Dynamic Message Signs (DMSs), as one of the important ITS devices, provide real-time traffic information of road network to drivers in order to improve route choice and relieve the traffic congestion. They warn of congestion, incidents, roadwork zones or speed limits on a specific highway segment. In order for the DMS to be effective, the following factors are important: (1) the location where they are positioned, (2) the type of information displayed, (3) the time interval from the incident occurrence and message display, and (4) the distance from the incident location to the DMS where messages are displayed.

The objective of the study is to evaluate whether dynamic message signs in the Las Vegas freeway systems have been effective in distributing incident/traffic information. Specifically, this study is to investigate whether incident/traffic information can be distributed to the motorists in a timely manner: at the right time and at right location and in the right format. For a dynamic message sign to be effective, the messages have been presented at the location where travelers can make a diversion to reach their destinations faster than if they keep using their original route. For the travelers to take the messages presented on the dynamic message sign, the messages can be understood, and the messages have to be reliable. In this study, whether the DMSs are activated at the right time and right place is investigated by touring the traffic management center FAST and by comparing the progression of congestion and the time when DMSs are activated. To evaluate the congestion progression, traffic and incident data are collected from the RTC FAST. The DMS log data are collected from the RTC FAST as well from which the DMS activation time can be obtained. From the comparison of the congestion progression and DMS activation, it can be determined whether the DMS are activated on time, whether other DMSs should be activated to notify more motorists to make diversion division. To evaluate whether the messages on DMSs are reliable and in the right format, surveys are distributed to travelers and truckers to get their opinions. To get reliable survey results from the general travelers, the surveys are distributed in various different ways. For truckers, survey was distributed to the Nevada Truck Association who helped get the responses from the trucking companies. Figure 1 presents the methodology adopted for this study.

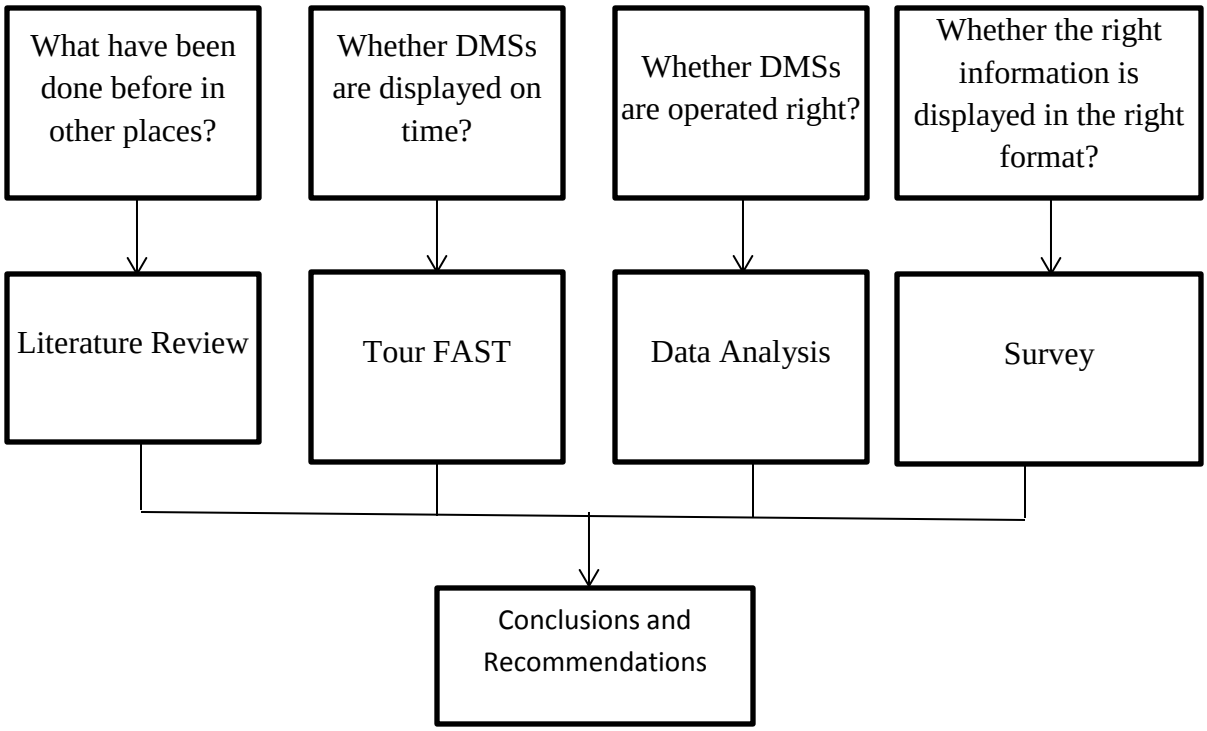


Figure 1 Research Methodology

In the following part of the report, the second chapter provides a literature review that covers the design and operation of DMSs, the evaluation of the effectiveness of DMSs in diverting traffic, and the technologies to improve the operations of DMSs. In the third chapter section, the tour to FAST is presented. The fourth chapter describes the comparison between congestion progress and DMS activation is presented. In the fifth chapter, the survey to travelers is covered. The last chapter provides the conclusions and recommendations.

Chapter 2 Literature Review

There are many studies and manuals such as Dudek (2004) and Dudek (2006) on how to present traffic and incident information on DMS so that travelers can perceive it clearly. These studies and manuals also provide recommendations on places to install DMS so travelers receiving the information have sufficient space to make a diversion decision. DMS has been used for many years in managing incidents, and some of these manuals have been the results of updating previous versions. In these recent versions of manual, it can be seen that displaying incident information on freeways than where incidents occur has been specially recommended. Some states like Texas and New Jersey have DMS manual developed for use by people involved in incident management in different level such as operators and manager in traffic management and control centers.

In recent years, some studies evaluated the effectiveness of the DMS in conveying congestion information so that travelers diverted to alternative routes to avoid traffic congestion (Levinson and Huo 2003, Edara et al, 2011, Hagani et al, 2013). In the study by Levinson and Huo (2003), a discrete choice model was developed to estimate the probability of route diversion, and statistical analysis was performed to evaluate the impact of VMS on travel time and delay in congestion. The results indicate that the messages on VMS do have significant impact on route diversion. The VMS does not influence the travel time on routes, but significantly reduce total delay for traffic in congestion.

Edara et al. (2011) evaluated the effectiveness of DMS is three different ways. They first conducted a survey to the personal vehicle drivers and commercial vehicle drivers about the perception of DMS. The results of the survey indicate that the motorists are very satisfied with the DMSs. They also investigated the impact of DMS on traffic in a work zone. It was indicated that the speed before traffic driving in the work zone are reduced significantly. In the third attempt, they evaluated whether traffic made diversion to other alternative route when there was a lane closure on freeway. The survey they conducted for this evaluation showed that the motorists were satisfied with the information provided on VMS.

Hagani et al, 2013 is a recent study that evaluated the effectiveness of DMS on speed and safety. The messages on DMS are categories into three types: Danger/Warning, Information/Common Road Conditions, and Regulatory/Non-Traffic Related. Three types of message display are evaluated: message display (off-on), removal (on-off) and switching (between any two types of message). The speeds in the first five minutes are compared with that in the second five minutes. The general finding is that traffic is not influenced by the message display. A 12 two-week study was also conducted to examine the aggregate effect of message display on speed. It was found that message display is not likely to cause congestion. This study also investigated the impact of DMS on safety and it was concluded that DMS is a safe tool to distribute incident information.

There have been studies on improving the performance of DMS. Rathi (2007) evaluated how to locate the DMSs on a traffic network using traffic simulation and control software. In their study, it is assumed that motorists would follow the guidance displayed on DMSs. The traffic simulation model MITSIMLab was to emulate the real traffic conditions, while the control software DynaMIT was to provide guidance based on the real traffic conditions.

Computerized traffic management and control for freeway systems is needed and many efforts have been made. When Intelligent Transportation Systems (ITS) was deployed in cities such as San Antonio, Texas, incident response library was developed in which the response strategies for incidents of different types on each freeway segment were specified. Corresponding to specific incident information, the strategies can be selected by operators for incident response. Instead of developing such a big database storing the incident response strategies, computer software has been developed making the decision making for incident management for effective. The two major software developed based on federal funds are DynaMIT (Burghout1999) and Dynasmart (Aved et al. 2007). Both can provide traffic guidance information online. They have been tested in several traffic management centers (TMC) in the U.S. So far, the two software packages have not been used in any TMCs due to the reliability of the guidance generated from the software and other practical reasons. The most recent effort of developing decision making system for traffic management is the work by Hadi et al. (2015). The computer tools developed in Hadi et al. (2015) are called ITS data capture and performance management, or ITSDCAP. One function of the tools is the decision support for traffic management center operations, including the prediction of incident impacts, calculation of the probability of breakdowns and assistance in construction management.

Chapter 3 Tour FAST Traffic Operation Center

To be familiar with the operations of dynamic message signs in traffic management, a tour was made to the FAST of the Regional Transportation Commission of Southern Nevada on December 12, 2014. During the tour, communications with the operation staff were made and the operations of dynamic message signs were observed.

It was found is that there was no computer aided incident response system in FAST (see Figure 2). There were one or two operators monitoring the traffic. When an incident occurs, an operator will decide when and where to display incident information based on his/her observations and experience. It was further observed that operators may not be experienced enough knowing when and where to use DMS to display incident information. Sometime operators may be distracted forgetting to turn on DMSs at certain location. It was the operator who types in messages to be displayed, with no assistance from any decision-making system.

On December 12, 2014, a Friday afternoon, an incident occurred on the median of I-215, marked as red in Figure 3, at about 1 pm when traffic was about becoming heavy (the peak starts at 2 pm). The traffic on both sides of the incident slowed down (see Figure 4). The congestion caused by this incident kept growing for a while. Then the DMSs on I-515 and I-15 were turned on because there was traffic from these freeways to go to the incident site. Note that the traffic from I-15 south bound to I-215 east bound needs to enter a separate diverging road even at Tropicana Ave. When there is congestion on I-215 eastbound, miles of traffic would have to stuck there, with no easy way out. What it appeared is that the operator may have turned these DMSs late. In addition, the operator only presented message: incident at Eastern Ave, from which travelers cannot tell the type of incident, how many lane closed, how far the congestion moves from the incident sites to where freeways intersect so that travelers can take different routes. It was also observed that the operator was really busy and fatigue, and could not follow up the progress of congestion.

These observations imply that that a computer aided system can monitor the process of incident and traffic and prompt the operator to display incident message, by which no delay would occur for displaying incident information. In addition, it also implies that more incident and traffic specific information should be provided such as number of lanes blocked and how far the congestion has grown to which part of the freeway network.

More than ten years ago when the City of San Antonio was chosen as the one of the four cities for initial ITS deployment, the TMC in San Antonio developed a computer aided incident management system where the computer can prompt the operators the decisions including where, when and how DMSs need to be turned on. The system include a library of such decisions for different scenarios of what types of incidents occurred at which segment of freeway network.

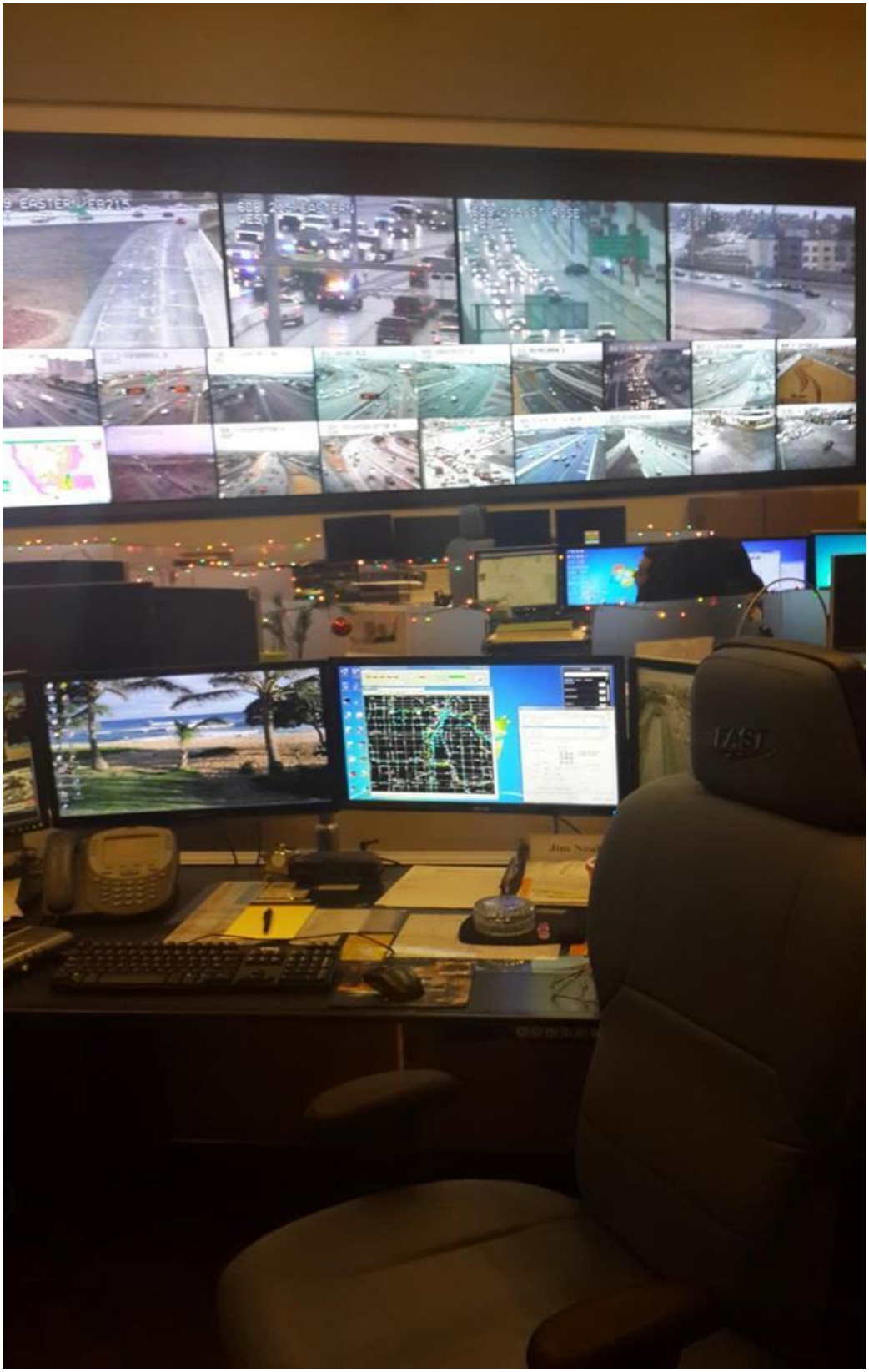


Figure 2 Working Space for an Operator at FAST

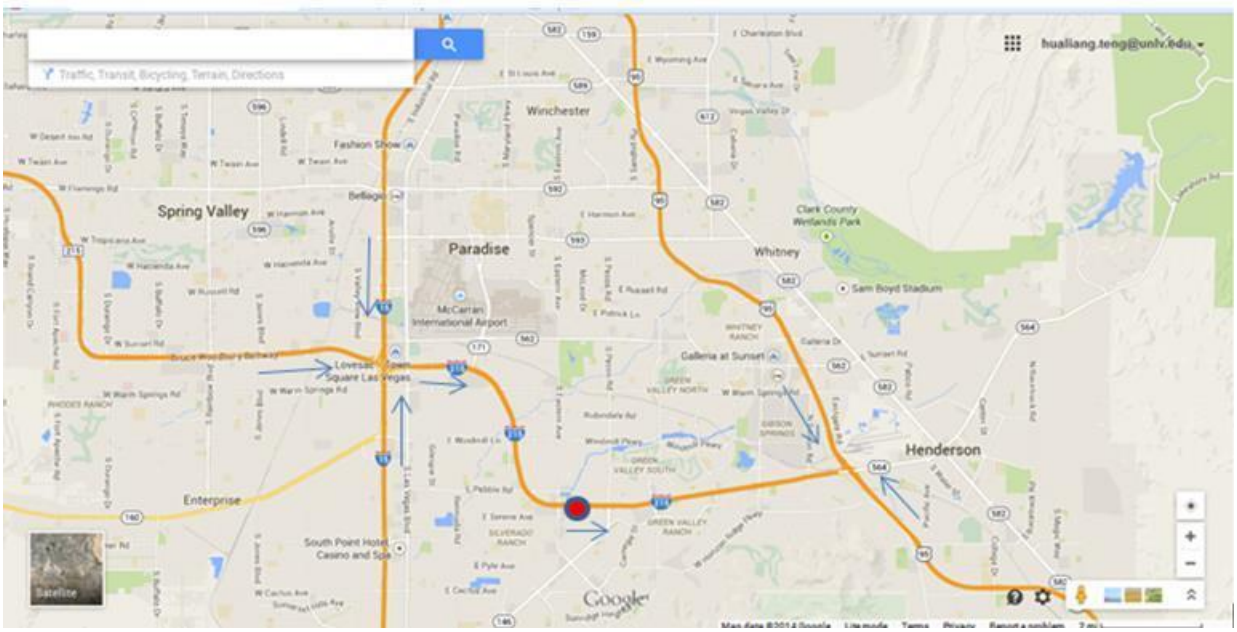


Figure 3 An Incident Occurred in the Median of I-215 on December 12, 2014

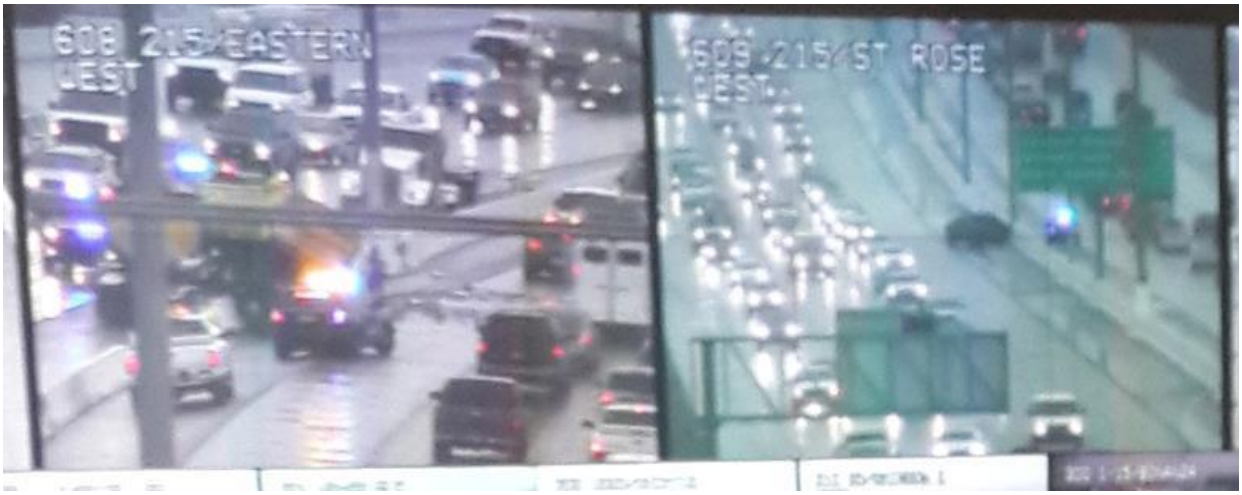


Figure 4 Snap Shots of the Crash from Two Different Cameras

Chapter 4 DMS Activation

One objective of the study is to verify whether dynamic messages signs have been used in a timely manner to provide incident/congestion information to the motorists for route diversion on freeways in the Southern Nevada. Specifically, it is to investigate whether the DMSs have been activated timely with the progress of incident/congestion. To determine whether a DMS at a location should be activated, the travel times from the location on freeway going through the congestion and that taking an alternative route are compared. Considering the existence of reliabilities of the travel time in congestion on freeways and that on alternative routes, these two routes can be viewed as comparable when their travel times are the same.

The calculation of travel time on freeway is based on time-space diagram as shown in Figure 5. The time starts from when an incident occurs and the space begins with the location where the incident occurs. The time incremental can vary based on the time interval for which traffic data are available such as one minute or 15 minutes. The freeway sections are those that have traffic sensors available to have traffic measurements such as volume, speed and occupancy. If we want to determine whether motorists at Location D can have the benefit for using alternative route, the travel time from D to A where the incident occurs can be calculated for Segments A-B and B-D, Traffic on Segment A-B is under congested condition while those on Segment B-D is under uninfluenced condition. The travel times for these two segments can be calculated based on the traffic flow measures in these two conditions. It can also be seen from Figure 5 that the travel time varies from time to time. After the incident is cleared, the travel time consists of three parts: one between the incident and the head of the congestion, one within the congestion, and the third between the tail of the congestion and where diversion point exists.

The travel time on the alternative route can be derived based on the speed limits on the route segments of the alternative route.

Two weeks (12/2/2014-12/16/2014) of traffic, incident and DMS log data were collected for northbound of I-15 from I-215 to US95. The traffic data are the one minute volume, speed, and occupancy. Six incidents occurred during this two weeks period on this road segment. The calculation of the travel times on freeways and alternative routes are calculated and presented for these six incidents.

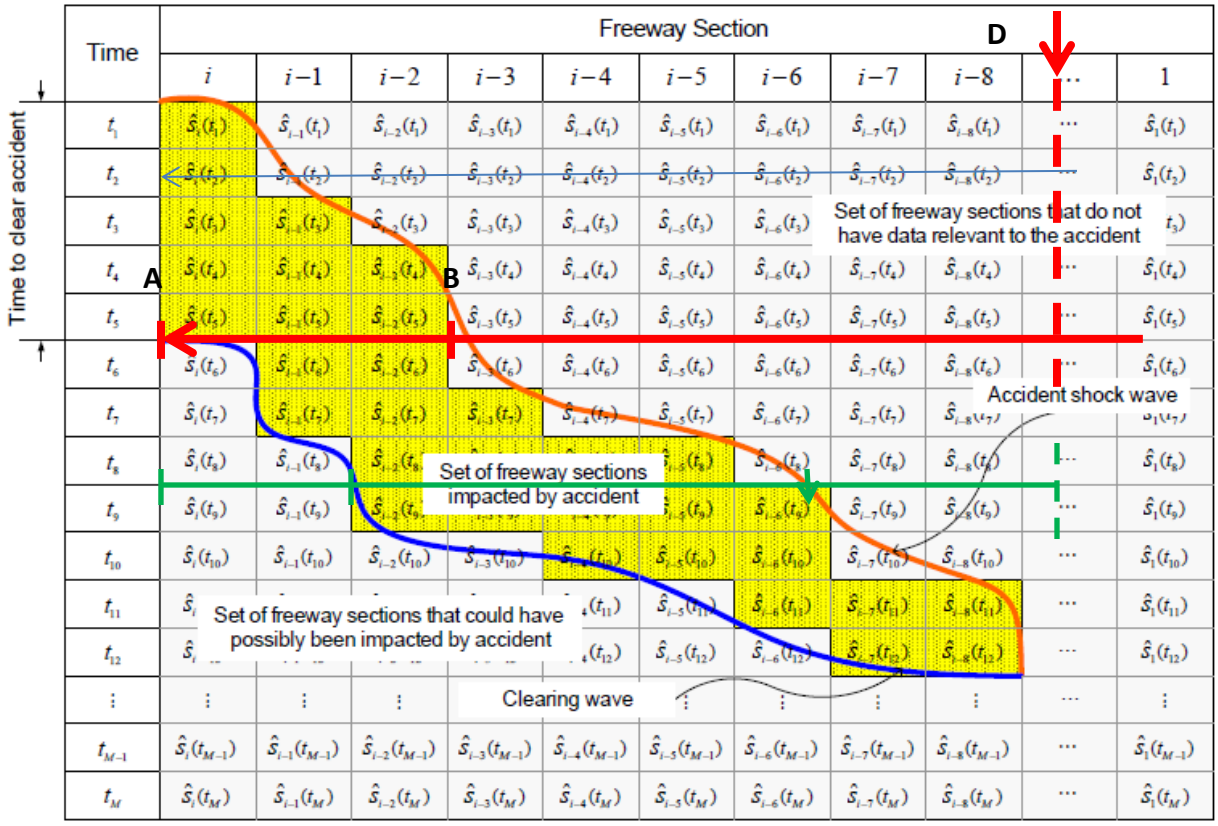


Figure 5 Time-Space Diagram for an Incident on Freeway (Recker et al. 2005)

Case 1 Crash on the North of Sahara Ave.

Case 1 involves the crash that occurred at the north of Sahara Avenue on December 5, 2014. See Figure 3 for the crash location. The crash occurred at 15:05 and blocked a right lane. Only one dynamic message sign (DMS) upstream the crash location displayed information about the crash. The location of the DMSs can be seen on Figure 7. The DMS 3 which is approximately 0.1 mile upstream the crash displayed the message about the crash one minute after the crash occurrence. Other DMSs upstream the crash location displayed the travel times only. The messages displayed on these DMSs are presented in Table 1, while their activation times are shown on Figure 8. The red box on Figure 8 indicate the time and location for the DMS displaying the crash information, and the orange boxes highlight the time and location for the DMS displayed the travel time only. The congestion effect of the crash existed for about three hours as highlighted by yellow color in Figures 8 and 9 below.

It can be seen from Figures 8 and 9 that the congestion back up to the point at the North of 215 Interchange on I-15 starting at 16:30 pm and stabilized there for one hour. On I-215, the congestion backed up to the point of West of Paradise Rd. and stayed there for about five

minutes. The crash information on DMS 3 cannot be helpful for motorist to take different routes because the DMS is located after the Sahara Interchange. It can be helpful only conveying the crash information to the motorists so that they know what happened downstream in the congestion. The impact of the crash is reflected on the travel times displayed on DMSs 2, 15, 1 and 80 where a long travel time to Craig Road crossing the congestion is shown. These DMSs were active online and can reflect the any change in travel time caused by crashes immediately. If motorists are sensitive to travel time messages, they would take actions accordingly, staying on I-15 or diverting to other routes.

The travel times displayed on DMSs 71 and 69 did not show the long travel times traversing the congestion. The motorists would be misled by the travel time information and continue their travel staying in the congestion only. This travel time issue implies that there might be an issue of the reliability of calculating travel time when there is congestion backing up from a different freeway. On I-215 before entering I-15, there are multiple lanes, some to the on-ramp congested and some going straight with no congestion. When calculating the travel times, the speed data from individual relevant lanes should be used, rather than using the average of the speeds measured from all the lanes.

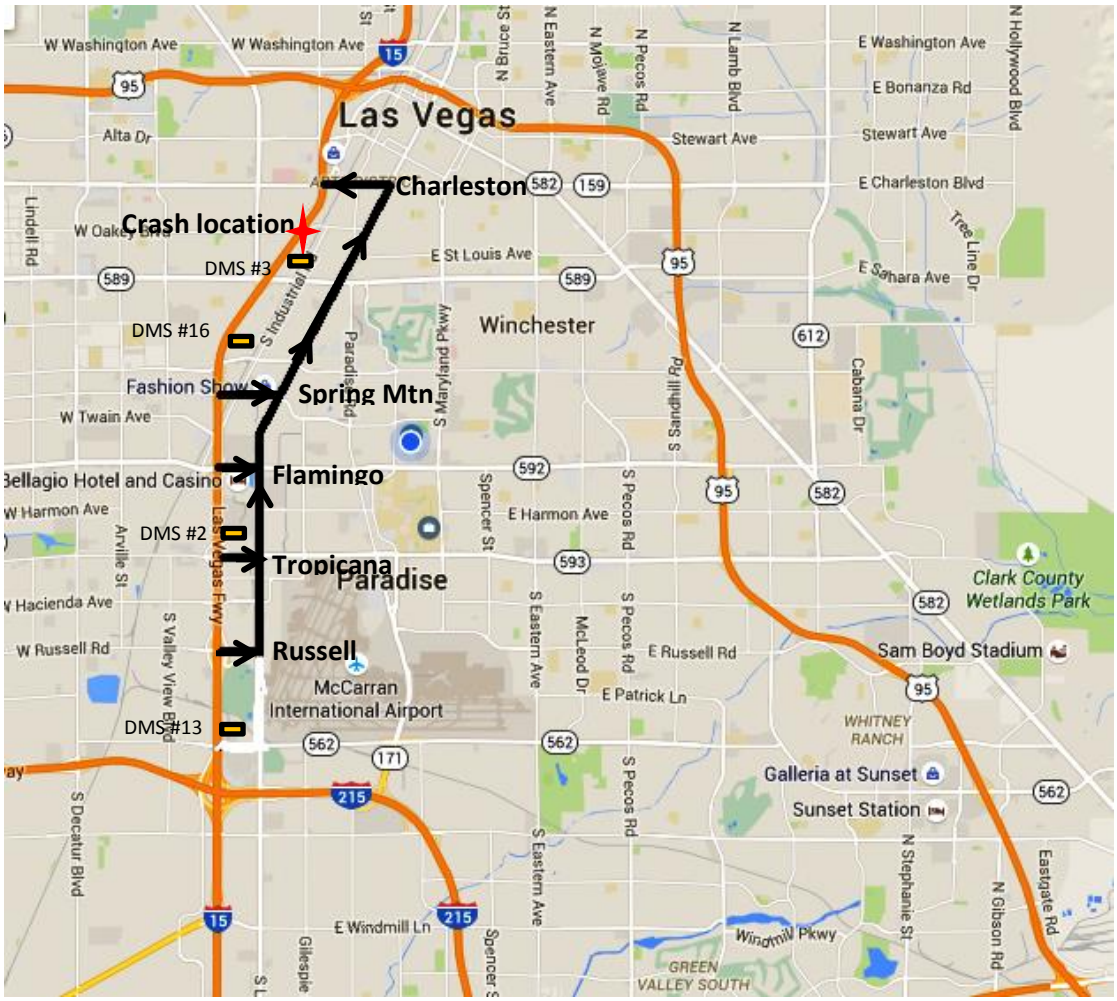


Figure 6 Incident Location and Alternative Routes for Vehicles on I-15

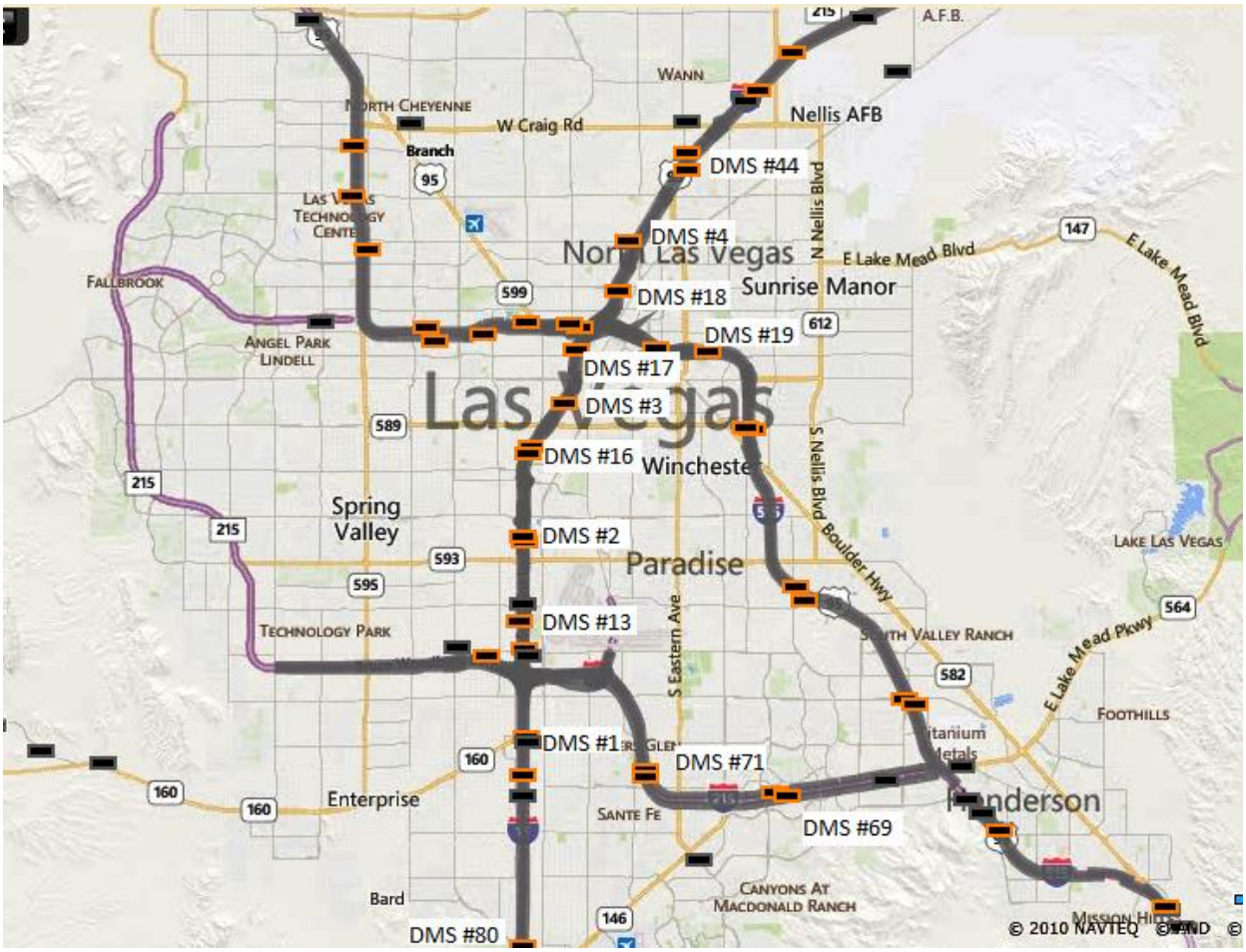


Figure 7 Dynamic Message Signs Locations

Table 1 Log Information of Dynamic Message Signs details for Case 1

DMS number	Route	DMS location	Distance from Crash	Message displayed
3	I-15	North of Sahara Ave.	0.1	CRASH SAHARA / KEEP LEFT
16	I-15	South of Sahara Ave.	1.45	
2	I-15	North of Tropicana	3.3	US-95 8 / LAKE MEAD BLVD 11 / CRAIG RD 14
13	I-15	North of I-215	5.6	SPRING MT 6 / US-95 12 / CRAIG RD 18
1	I-15	South of Blue Diamond	7.6	FLAMINGO 7 / US-95 15 / CRAIG 20
80	I-15	North of St. Rose Pkwy	12.6	6/ 10/ 19
71	I-215	West of Eastern Ave.	10.6	4 /8 /8 /
69	I-215	East of Green Valley Pkwy	13.6	7 /11 /11 /

Location	South of Oakey	North of Sahara	South of Sahara	South of Sahara	North of Desert Inn	South of Desert Inn	South of Spring Mtn	North of Flamingo	South of Flamingo	South of Harmon Ave	North of Tropicana	South of Russell	North of I-215	South of Warm spring	North of Blue Diamond	South of Blue Diamond
Distance	0.08	0.5	0.84	1.08	1.51	1.79	2.06	2.67	3.1	3.32	3.6	4.98	6.19	7.24	7.57	7.9
Time																
15:06	31.8	18.6	29.8	32.5	61.2	68.3	57.3	65.3	64.0	56.0	58.5	67.7	52.7	66.3	75.7	68.7
15:08	24.4	18.6	34.7	33.0	63.2	69.0	56.3	62.3	64.0	61.4	56.8	58.3	50.7	66.5	72.0	69.3
15:11	16.0	14.6	24.3	29.5	57.8	65.3	55.0	63.0	63.3	61.8	61.8	64.7	51.0	65.3	73.0	68.0
15:16	22.0	23.2	28.7	28.3	25.7	18.5	36.3	62.0	63.5	59.0	51.8	64.3	51.7	66.8	77.3	69.3
15:21	24.6	17.6	24.2	20.2	24.5	22.8	27.0	58.0	61.3	56.6	59.5	62.3	63.9	65.5	75.3	68.3
15:26	27.6	21.6	31.0	24.3	24.7	17.0	19.3	58.7	60.5	60.6	53.5	63.7	58.3	64.8	75.7	69.3
15:31	21.2	24.0	29.3	27.0	36.5	25.5	27.7	45.0	55.3	53.8	53.5	63.3	59.0	65.0	74.7	70.0
15:36	20.8	21.6	31.0	24.3	24.7	17.0	19.3	58.7	52.8	53.2	59.0	65.3	53.7	65.8	76.0	66.7
15:41	24.4	19.6	24.7	20.5	23.5	23.3	27.3	47.3	58.5	59.8	59.0	65.0	48.3	66.5	75.0	71.0
15:46	24.4	15.2	25.5	23.7	15.7	21.0	21.7	46.3	58.0	57.6	56.0	60.3	54.0	88.5	77.0	72.0
15:51	24.6	18.0	24.7	18.8	25.0	19.5	32.9	46.3	58.8	60.2	49.5	60.7	53.3	66.5	76.3	70.3
15:56	26.8	20.2	22.2	25.3	22.2	20.5	25.3	48.7	57.5	55.4	51.5	63.0	64.9	66.8	73.3	71.7
16:01	29.4	19.6	29.8	32.3	22.8	24.5	20.7	50.3	55.3	52.8	43.0	65.7	54.7	68.0	76.0	70.3
16:06	22.2	18.0	26.5	26.0	27.0	20.5	27.3	49.3	56.0	56.0	54.8	59.7	52.3	68.0	75.0	70.0
16:11	23.0	20.6	29.3	24.0	23.7	18.5	24.0	50.0	58.8	55.8	61.0	64.0	59.0	87.5	78.3	66.3
16:16	26.8	26.8	24.3	24.2	25.0	21.8	23.0	47.0	59.0	53.6	48.3	61.0	55.7	66.0	75.3	65.0
16:21	27.8	22.6	26.8	25.2	32.5	39.3	24.3	32.3	47.3	58.0	55.8	60.7	54.0	66.8	74.7	69.7
16:26	30.4	17.4	33.8	34.0	22.3	38.0	24.0	40.7	48.0	51.6	32.9	64.7	58.3	67.5	73.7	67.0
16:31	31.6	22.2	27.3	26.2	26.5	28.5	17.0	41.7	54.5	53.6	54.0	57.7	51.7	67.0	76.7	24.3
16:36	27.0	19.4	27.0	21.7	34.5	20.8	22.7	38.6	54.5	57.4	52.8	54.0	51.3	65.3	75.3	59.3
16:41	23.4	23.0	27.0	22.2	33.5	18.0	21.7	27.7	51.0	56.2	51.5	62.7	53.0	64.5	74.3	70.0
16:46	27.4	23.0	27.0	21.8	25.5	30.5	32.0	27.3	49.8	47.8	41.3	63.7	81.3	65.5	75.3	68.7
16:51	29.2	24.2	25.3	25.7	23.2	19.8	29.5	39.3	38.5	45.6	48.3	62.7	56.3	67.0	75.3	68.0
16:56	28.6	20.4	27.2	25.7	22.2	33.0	24.3	27.7	39.9	52.2	47.8	54.3	53.7	87.8	74.3	71.7
17:01	37.2	19.8	26.7	29.7	20.8	25.0	22.3	28.3	40.8	44.0	50.3	57.0	54.3	87.5	75.3	69.3
17:06	27.8	20.0	29.0	28.2	30.0	25.0	24.0	31.0	48.5	45.8	50.8	56.7	89.3	65.0	75.7	68.3
17:11	30.6	23.6	24.8	25.3	25.2	19.5	20.3	30.7	45.3	48.0	50.8	42.7	50.0	65.8	75.3	69.7
17:16	26.6	20.8	25.7	26.7	25.8	19.5	22.7	24.0	47.0	48.6	49.0	52.0	52.3	67.5	77.7	68.7
17:21	25.8	19.4	21.2	26.2	29.5	21.3	24.0	24.0	37.5	54.0	45.5	44.8	50.0	66.3	72.7	68.0
17:26	27.6	20.0	26.0	23.0	25.2	21.8	25.3	29.0	48.3	49.8	51.5	49.3	53.7	65.5	75.3	69.3
17:31	28.8	20.4	25.8	22.2	22.0	20.0	19.7	42.7	65.8	51.4	20.0	61.0	53.3	66.8	73.3	68.0
17:36	32.4	22.8	24.7	28.5	26.2	18.8	22.0	66.7	61.5	54.2	19.3	62.0	54.0	67.0	74.7	70.3
17:41	30.0	17.8	25.5	23.3	24.2	68.0	57.0	67.7	65.8	54.2	21.5	60.0	51.0	66.8	75.7	69.7
17:46	27.8	24.2	23.0	21.7	65.2	70.8	62.7	63.0	62.5	49.2	19.5	60.3	52.3	66.8	74.3	69.7
17:51	33.6	33.2	47.8	52.0	69.3	68.5	67.7	66.7	63.0	53.4	16.8	62.3	53.0	67.3	76.0	71.7
17:56	63.2	63.8	63.7	66.5	67.8	70.5	56.3	64.3	64.3	52.8	19.5	61.7	52.7	67.0	76.3	71.3
18:01	65.2	67.2	67.1	67.0	89.0	101.8	59.0	127.0	127.0	52.6	95.3	63.7	52.7	68.0	73.7	69.3

Figure 8 Vehicle Speeds in I-15

Location	South of Oakey	North of Sahara	South of Sahara	South of Sahara	North of Desert Inn	South of Desert Inn	South of Spring Mtn	North of Flamingo	South of Flamingo	South of Harmon Ave	North of Tropicana	South of Russell	North of I-215	East of Las Vegas Blvd	West of Paradise Rd	East of Paradise Rd	East of Warm Spring	West of Windmill	East of Windmill	At Pebble Rd	West of Eastern	East of Eastern
Distance (mi)	0.08	0.5	0.84	1.08	1.51	1.79	2.06	2.67	3.1	3.32	3.6	4.98	6.19	7.24	8.03	8.42	9.03	9.41	10.18	10.89	11.4	11.84
Time																						
15:06	31.8	18.6	29.8	32.5	61.2	68.3	57.3	65.3	64.0	56.0	58.5	67.7	52.7	69.7	67.2	67.3	67.0	69.3	70.7	64.7	68.0	65.7
15:08	24.4	18.6	34.7	33.0	63.2	69.0	56.3	62.3	64.0	61.4	56.8	58.3	50.7	65.3	69.0	67.8	68.3	67.5	65.3	63.7	73.7	67.7
15:11	16.0	14.6	24.3	29.5	57.8	65.3	55.0	63.0	63.3	61.8	61.8	64.7	51.0	65.3	66.8	69.8	70.0	69.3	67.3	65.7	70.0	63.3
15:16	22.0	23.2	28.7	28.3	25.7	18.5	36.3	62.0	63.5	59.0	51.8	64.3	51.7	64.0	66.4	67.5	68.5	70.3	69.7	66.3	71.3	64.0
15:21	24.6	17.6	24.2	20.2	24.5	22.8	27.0	58.0	61.3	56.6	59.5	62.3	63.9	67.7	69.4	69.3	70.0	68.5	66.0	61.3	70.0	61.0
15:26	27.6	21.6	31.0	24.3	24.7	17.0	19.3	58.7	60.5	60.6	53.5	63.7	58.3	67.0	68.0	68.3	66.0	66.0	66.7	62.0	69.0	64.0
15:31	21.2	24.0	29.3	27.0	36.5	25.5	27.7	45.0	55.3	53.8	53.5	63.3	59.0	66.3	65.4	68.5	67.8	68.5	64.7	64.7	64.0	60.3
15:36	20.8	21.6	31.0	24.3	24.7	17.0	19.3	58.7	52.8	53.2	59.0	65.3	53.7	62.3	53.2	69.0	69.0	64.5	67.7	63.0	73.0	67.0
15:41	24.4	19.6	24.7	20.5	23.5	23.3	27.3	47.3	58.5	59.8	59.0	65.0	48.3	62.7	61.4	68.5	70.0	71.5	71.0	60.0	68.7	63.7
15:46	24.4	15.2	25.5	23.7	15.7	21.0	21.7	46.3	58.0	57.6	56.0	60.3	54.0	61.3	65.4	66.5	67.3	68.8	70.7	66.0	67.3	62.0
15:51	24.6	18.0	24.7	18.8	25.0	19.5	32.9	46.3	58.8	60.2	49.5	60.7	53.3	61.7	55.6	71.0	71.0	69.3	69.3	70.0	70.0	64.0
15:56	26.8	20.2	22.2	25.3	22.2	20.5	25.3	48.7	57.5	55.4	51.5	63.0	64.9	62.7	66.0	71.0	71.0	71.5	68.3	59.7	68.3	61.7
16:01	29.4	19.6	29.8	32.3	22.8	24.5	20.7	50.3	55.3	52.8	43.0	65.7	54.7	64.7	68.0	65.3	65.3	68.0	67.3	64.3	70.0	62.7
16:06	22.2	18.0	26.5	26.0	27.0	20.5	27.3	49.3	56.0	56.0	54.8	59.7	52.3	64.7	68.0	66.3	68.8	70.0	69.3	68.7	70.7	59.7
16:11	23.0	20.6	29.3	24.0	23.7	18.5	24.0	50.0	58.8	55.8	61.0	64.0	59.0	64.7	68.8	67.8	66.5	67.3	67.3	60.7	69.3	66.7
16:16	26.8	26.8	24.3	24.2	25.0	21.8	23.0	47.0	59.0	53.6	48.3	61.0	55.7	68.3	68.6	67.0	68.0	67.8	66.3	58.7	68.0	63.3
16:21	27.8	22.6	26.8	25.2	32.5	39.3	24.3	32.3	47.3	58.0	55.8	60.7	54.0	60.0	66.0	65.0	65.3	66.3	66.7	65.0	68.7	61.3
16:26	30.4	17.4	33.8	34.0	22.3	38.0	24.0	40.7	48.0	51.6	32.9	64.7	58.3	65.7	65.0	69.3	69.5	66.3	71.3	64.3	70.7	63.3
16:31	31.6	22.2	27.3	26.2	26.5	28.5	17.0	41.7	54.5	53.6	54.0	57.7	51.7	65.7	66.4	67.0	67.5	69.5	70.0	68.0	68.3	65.7
16:36	27.0	19.4	27.0	21.7	34.5	20.8	22.7	38.6	54.5	57.4	52.8	54.0	51.3	66.3	68.2	68.3	68.8	69.0	65.0	53.7	67.7	66.0
16:41	23.4	23.0	27.0	22.2	33.5	18.0	21.7	27.7	51.0	56.2	51.5	62.7	53.0	62.0	65.4	69.8	70.0	70.8	68.7	66.0	71.0	64.3
16:46	27.4	23.0	27.0	21.8	25.5	30.5	32.0	27.3	49.8	47.8	41.3	63.7	81.3	61.3	62.2	67.0	68.8	65.8	66.7	65.3	67.3	64.7
16:51	29.2	24.2	25.3	25.7	23.2	19.8	29.5	39.3	38.5	45.6	48.3	62.7	56.3	58.7	66.6	68.5	68.3	69.0	64.3	63.7	66.3	58.7
16:56	28.6	20.4	27.2	25.7	22.2	33.0	24.3	27.7	39.9	52.2	47.8	54.3	53.7	57.7	59.6	67.3	70.0	64.5	66.0	57.7	65.3	62.0
17:01	37.2	19.8	26.7	29.7	20.8	25.0	22.3	28.3	40.8	44.0	50.3	57.0	54.3	63.3	63.6	66.5	67.3	64.8	63.3	64.3	68.7	59.0
17:06	27.8	20.0	29.0	28.2	30.0	25.0	24.0	31.0	48.5	45.8	50.8	56.7	89.3	59.0	48.2	67.3	67.0	67.5	63.3	64.3	67.3	60.3
17:11	30.6	23.6	24.8	25.3	25.2	19.5	20.3	30.7	45.3	48.0	50.8	42.7	50.0	60.3	53.2	63.0	67.0	67.3	63.3	60.3	64.7	59.3
17:16	26.6	20.8	25.7	26.7	25.8	19.5	22.7	24.0	47.0	48.6	49.0	52.0	52.3	37.3	38.0	62.5	66.0	65.5	63.7	64.3	64.3	58.3
17:21	25.8	19.4	21.2	26.2	29.5	21.3	24.0	24.0	37.5	54.0	45.5	44.8	50.0	46.3	55.6	64.8	65.5	64.5	64.7	59.7	65.3	61.7
17:26	27.6	20.0	26.0	23.0	25.2	21.8	25.3	29.0	48.3	49.8	51.5	49.3	53.7	55.0	40.2	64.8	67.5	65.3	64.7	56.0	65.3	61.3
17:31	28.8	20.4	25.8	22.2	22.0	20.0	19.7	42.7	65.8	51.4	20.0	61.0	53.3	55.0	40.6	66.3	66.5	64.5	64.3	67.7	70.0	61.7
17:36	32.4	22.8	24.7	28.5	26.2	18.8	22.0	66.7	61.5	54.2	19.3	62.0	54.0	39.0	36.0	67.3	68.3	68.8	65.3	56.7	66.7	57.3
17:41	30.0	17.8	25.5	23.3	24.2	68.0	57.0	67.7	65.8	54.2	21.5	60.0	51.0	27.7	45.0	66.8	67.3	65.8	67.0	63.0	69.3	60.7
17:46	27.8	24.2	23.0	21.7	65.2	70.8	62.7	63.0	62.5	49.2	19.5	60.3	52.3	54.7	37.6	66.8	67.5	66.8	64.0	68.0	67.3	59.7
17:51	33.6	33.2	47.8	52.0	69.3	68.5	67.7	66.7	63.0	53.4	16.8	62.3	53.0	63.0	63.0	66.8	68.8	70.5	67.7	67.7	71.0	59.0
17:56	63.2	63.8	63.7	66.5	67.8	70.5	56.3	64.3	64.3	52.8	19.5	61.7	52.7	70.7	69.8	66.3	67.0	69.0	68.0	62.7	69.3	64.3
18:01	65.2	67.2	67.1	67.0	89.0	101.8	59.0	127.0	127.0	52.6	95.3	63.7	52.7	68.0	73.7	69.3	82.0	59.0	67.5	71.8	66.3	67.3

Figure 9 Vehicle Speeds for Vehicles on I-15 and I-215

Should DMSs displaying travel time be activated to show crash information, in case motorists are not sensitive to travel time information? In Case 1, DMSs 16, 2, 13, 1 are the signs having this issue. DMSs 80, 71, 69 are travel time sign, not changing the destination of trips. Thus, the travel times on freeway and the alternative routes are calculated and compared.

In this study, Las Vegas Boulevard is viewed as the alternative route to avoid the congestion due to crash. It is known that diverting traffic to LV Blvd is very sensitive to the casinos. The detour locations are assumed to be at Spring Mountain Rd., Flamingo Rd, Tropicana Ave., and Russel Rd. as shown in Figure 6 for the vehicles that were already on I-15 highway. For vehicles that were on the West I-215, the alternative routes to avoid congestion were Las Vegas Boulevard and Eastern Avenue as shown in Figure 10.

The travel times for detour routes were computed and compared to the equivalent travel times if the vehicle could continue using I-215 and I-15. The travel time through the detour routes was computed by considering the speed and the respective distance from the detouring point to location where the road user will merge to the I-15. From Table 2 it can be seen that staying on I-15 would experience shorter travel times on average than diverting using Las Vegas Boulevard from Spring Mountain Rd., Flamingo Rd., Tropicana Ave., and Russell Ave. The same situation occurs for motorists if they want to divert at Las Vegas Boulevard and Eastern Ave. on I-215. To be noted that even though the travel times going through the congestion caused by the crash on freeway is shorter than that on alternative urban streets, because of the uncertainty in the travel on the freeway and streets, there are still probability, which could be smaller than 50%, that the travel on the alternative routes actually take shorter time. In this sense, it might still be beneficial for some travelers to know the congestion and its extent and let them to make diversion decisions. Figure 5 highlights the location and the time to display crash information from which travelers can receive their travel benefits. It can be seen that the red dash line in Figure 5 connects the spaces before reach which at a particular time motorists can divert to alternative routes.

Case 2 is for the crash occurred at Tropicana Avenue on 12/5/2014 around 5:35:00 PM. It resulted in blockage of two express lanes. The speed time-speed diagram does not show significant impact this crash caused to other traffic. In Case 3, a crash occurred south of Sahara Avenue on 12/5/2014 at 17:46. Among the six lanes available at this location, only one center lane was blocked. The incident lasted for 5 minutes before being cleared. Thus, no significant influence on traffic is observed. Case 4 encompasses a crash dated 12/6/2014 occurred at Tropicana Avenue around 1:14:00 PM. This crash resulted into one lane closure at the section with 3 lanes. No significant impact on traffic was observed. The crash in Case 5 occurred on 12/10/2014 around 8:22:00 PM south of Charleston Boulevard. It blocked a right lane at a section with five lanes and took 78 minutes to be cleared. Significant impact on traffic was observed. The travel time on freeway is calculated shorter than those on alternative routes. For the sixth crash happened during the two week data collection period, there is no specific data available to this study.

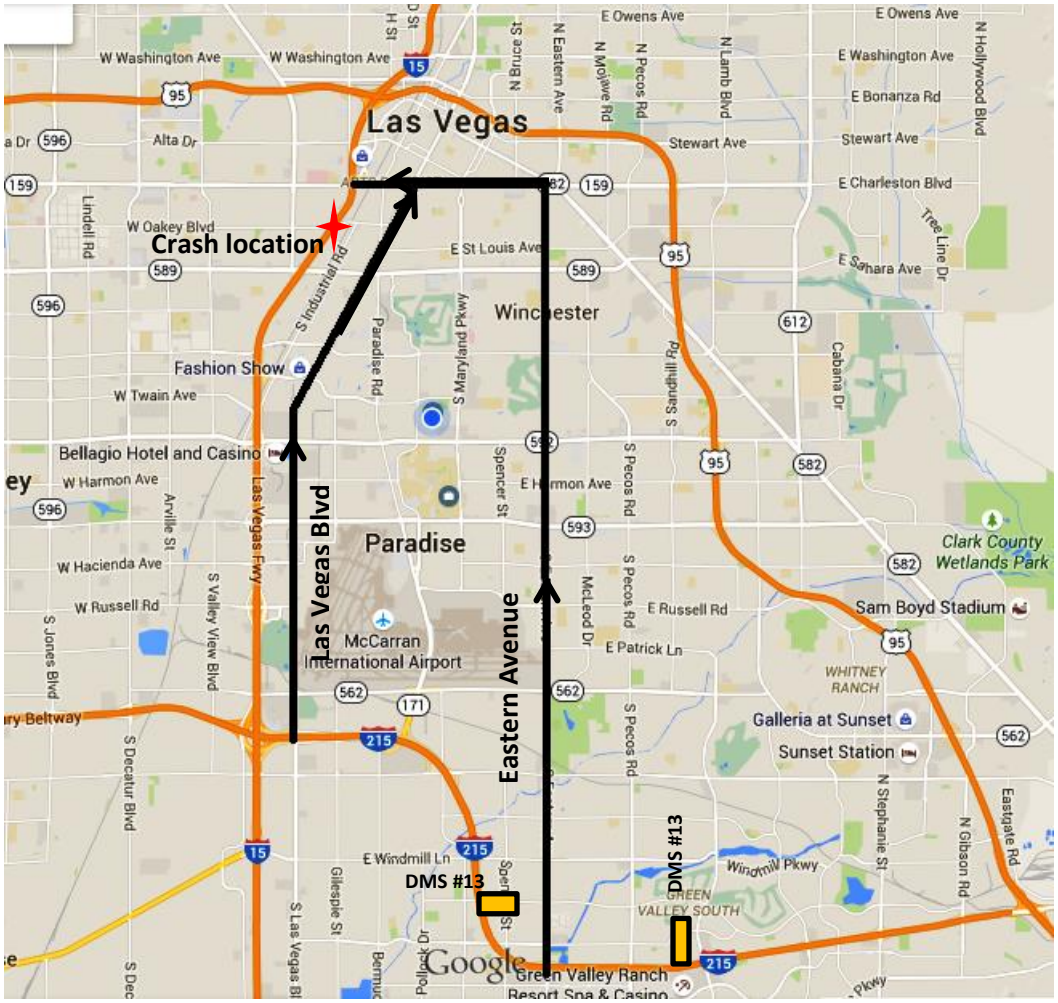


Figure 10Alternative Routes for Vehicles on I-215

Table 2 Travel Times for Vehicles in I-15

Detour locations	Spring Mtn	Flamingo	Tropicana	Russell
Travel time through detours routes (min)	5.9	6.8	8.2	9.8
Equivalent travel time through I-15 (min)	4	5	6	7

Table 3 Travel times for Vehicles in I-215

Detour locations	Eastern Ave	Las Vegas Boulevard
Travel time through detours routes (min)	17.5	11.4
Equivalent travel time through I-215 and I-15 (min)	13.5	9.3

Based on the analysis on the operations of DMSs and congestions caused by crashes, the following observations can be made.

First, the number of DMSs that can display crash information may not be sufficient. Traffic congestion may progress to location where DMSs displaying travel time only were activated. Motorists who are not sensitive to travel time can receive benefit from the crash information displayed on the DMS. The observation can be found in Cases 1 and 5. Thus, such DMSs should be activated correspondingly.

Second, some DMSs may not display reliable travel time during congestion conditions. This can be observed from Case 1. Improvement on algorithms to calculate travel time in congestion conditions can be made.

Third, the recording of DMS operation should be accurate. It is found in one case that the DMS activation times are earlier than the time a crash happened. It may be either the crash occurrence time is entered incorrectly, or the DMS data is recorded with error.

Fourth, it should be recognized that some motorists may still receive benefits by taking alternative route even though the calculated average travel time on freeway is shorter than those on alternative route. It is because there are uncertainties in both travel times. It may need to be investigated the condition for activating DMS based on the comparison of travel times on freeways and on urban streets. The uncertainties in the calculated travel time come from many aspects. For example, some motorists may choose to take faster moving lanes in congested freeway, by which they may experience shorter travel time than average travelers.

Chapter 5 Survey to Travelers

To evaluate whether the Dynamic Message Signs in the Las Vegas area present the incident/congestion information in the right way, two surveys were designed, one for general travelers and the other for truckers. These two surveys are included in appendixes B and C, respectively.

In the survey to general travelers, questions were asked about where they live in the Las Vegas area, how frequent they use the freeway systems, their attitude to use alternative route, whether the DMSs help them to take alternative route, whether the DMS presents sufficient information about crashes that are critical to their choosing routes, and whether the DMS presents the information in the right form. In the last, the social economic background information of the travelers was inquired.

The surveys were converted to Qualtrics format, which allows travelers to fill out the survey online. In conducting the survey, the potential travelers were provided with the web link to the survey. To get the web link known to the travelers, the survey was distributed first to the casinos which were declined. It was distributed to the cities and county in the Las Vegas area by asking their administration to email the survey to their employees, which is quite effective. The research team also contacted the Nevada Division of Motor Vehicles who posted these two surveys to their website. Because the posting do not appear outstanding, the responses may not be significant. The traveler survey was distributed to the University of Nevada, Las Vegas (UNLV) through announcing the survey on UNLV Today, as news location, which turned out to generate significant responses. In total, 190 responses were collected.

Similar questions were included in the survey to truckers. It was sent to the Nevada Trucking Association who is supposed to distribute the web links to their members. Unfortunately, only a few responses were returned.

In the following section, only the survey to the travelers is analyzed question by question because significant responses were received.

1. In what area do you live?
   Your zip code: _____

   Figure 11 presents the distribution of the survey response by zip code in Las Vegas. It can be seen that the responses were well distributed over the entire metropolitan area.

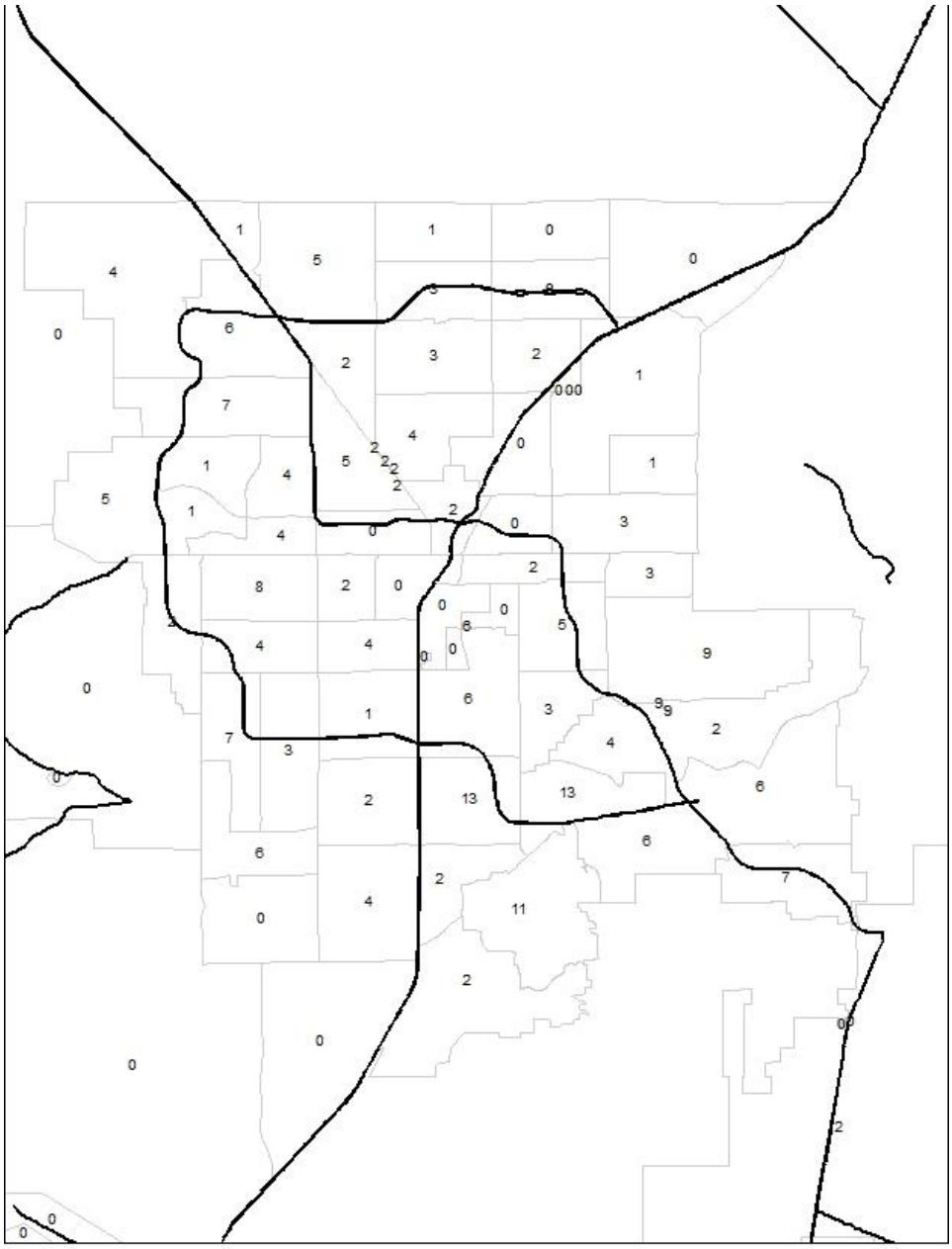


Figure 11 Survey Responses Distribution by Zip Code in Las Vegas

2. How frequently do you use highways as opposed to city streets in Las Vegas?
   □ Once or more than once a day □ Once a week □ Less than once a week

   Among the 190 travelers who asked this question, 167 indicates that they use highways once or more than once a day, and 23 and 19 replies that they use highways once a week or less than once a week.

3. When you run into congestion, do you take alternative routes?
   □ Yes □ No

   Among the 209 travelers asked this question, 169 travelers replied that they would take alternative routes when they run into congestion, and the remaining 40 indicate that they would not take alternative routes.

4. If your answer to Question 3 is "No", the reasons for not taking alternative routes are:
   □ I am not familiar with the highways and streets in Las Vegas.
   □ There are no convenient alternative routes in Las Vegas.
   □ Others, specify _____

   Among the 40 travelers who do not want to take alternative routes when they run into congestion, 3 answered that they are not familiar with the highways and streets in Las Vegas, 24 indicate that there are no convenient alternative routes in Las Vegas, and 13 (see the table below) provided different reasons among which the popular one is that the freeways are still faster than taking alternative route, particularly when there is no major congestion.

Table 4 Other Reasons for Not Taking Alternative Routes

1	will take same amount of time
2	Highways are still faster
3	Just wait it out, usually not more than 10 minutes
4	Surface streets take just as long unless there is a major accident on the freeways.
5	It's a gamble- assuming others are taking alternate routes, causing congestion WITH lights to deal with
6	Surface Streets are slower than waiting out congestion on interstate most of the time.
7	Usually faster to stick it out. If it is real bad I will take alternative route.
8	usually stuck between off ramps 93/95 SB
9	depends on the time constraints
10	Sometimes I do, but by the time I realize the congestion, I am stuck in it.
11	hard to get off freeway
12	There is construction every where now. All routes are ruined by the poor planning in this community
13	By the time I use the alternate route It will take me the same time as just remaining on the freeway. With Exception to large accidents, then I will take an alternative route.

5. If your answer to Question 3 is "Yes", do you take an alternative route only when you see slow traffic, regardless of the messages displayed on the dynamic message sign?
   □ Yes □ No □ Not sure

   Among the 169 travelers who want to take alternative routes, 51 would take action only when they see congestion on road, 104 (60%) of them would take diverting actions when they see congestion messages, and 14 of them are not sure whether they take alternatives when the see congestions.

6. Would you take an alternative route if you are provided with accurate information about incident/congestion by the dynamic message signs?
   □ Yes □ No □ Not sure

   It is confirmed that 189 travelers (90% of all the travelers responded) would take alternative routes if accurate information about incident/congestion is provided by the dynamic message sign.

7. Do you think the incident/congestion information on the dynamic message signs in the Las Vegas area is useful for your travel?

□ Yes □ No □ Not sure

186 travelers clearly indicate that the incident/congestion information on the dynamic message signs in the Las Vegas area is useful for their travel, which is 87% of the travelers answering Yes or No.

8. Is the information on the dynamic message signs clear about the location and severity of incident and congestion?

Location (e.g., crash at Sahara Ave. on N I-15)	□ Yes	□ No	□ Not sure
Severity (e.g., injury, fatality)	□ Yes	□ No	□ Not sure
Severity (e.g., blocked two lane)	□ Yes	□ No	□ Not sure
Severity (e.g., last half hour already)	□ Yes	□ No	□ Not sure
Severity (back up to Blue Diamond)	□ Yes	□ No	□ Not sure

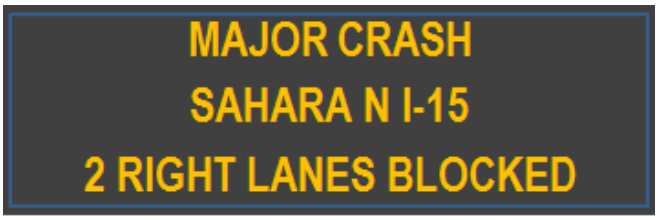
In order to identify the ways to improve the performance of the dynamic message signs, five categories of information are specified: location of crashes, severity in terms of fatality or injury, lane blockage, incident duration in real time, and back-up of congestion ("scale" in Table 5). The responses indicate that the current DMSs can provide pointy locational information about incidents only, not the severity of crashes. It implies that the DMSs should be improved for providing such information items clearly. The least provided is the information on incident duration.

Table 5 Information Needs for Incident/Congestion

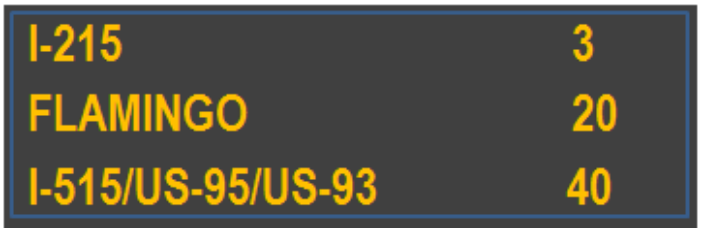
	Location	Injury	Blockage	Duration	Scale
Yes	0.81	0.39	0.62	0.29	0.52
No	0.13	0.34	0.24	0.46	0.29
Not Sure	0.07	0.27	0.14	0.25	0.19

9. If you are driving on I-215 to the West at Eastern Avenue, and there is a crash at Sahara Avenue on I-15 Northbound in the route you plan to travel, which of the following three signs best communicate the traffic congestion caused by the crash and possible alternative routes?

1 = the best, 2 = the second best, and 3 = the third best.



Dynamic Message Sign



Travel Time Sign

Dynamic Traffic Display Board (red shows congested area)

Sign Type	Rank
Dynamic Message Sign	
Travel Time Sign	
Dynamic Traffic Display Board	

To further identify the possible improvement in displaying the evolving congestion back-up, a dynamic traffic display board, that is popular in other countries, is presented to travelers to seek their opinion. The travelers are asked to compare this board with the existing DMS and travel time sign by ranking them. The results listed in the table below indicate that the 72% of the times DMS is chosen as the best, while the travel time sign and map board are chosen as the best by 13% and 18%, respectively. The average rankings and the standard deviation of the ranking for these three signs and board are also listed in the table below. The DMS is

ranked 1.33 on average while the other two are ranked as 2.36 and 2.28 respectively. The average rankings are compared the statistically, which clearly indicated that DMS is ranked higher.

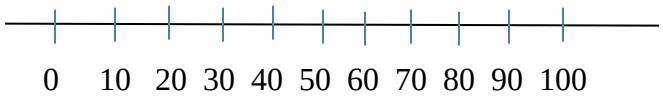
Table 6 Rankings for DMS, Travel Time Sign and Map Board

	DMS	Travel Time	Map Board
The Best (%)	0.72	0.13	0.18
The 2nd Best (%)	0.23	0.39	0.37
The 3rd Best (%)	0.05	0.49	0.46
Average ranking	1.33	2.36	2.28
STDEV	0.57	0.70	0.74

10. Which of these three signs do you prefer? Please mark your rating on the scales below.

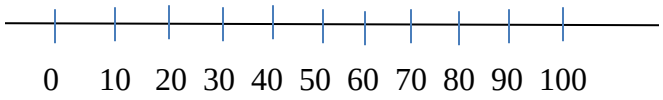
Dynamic Message Sign

Least preferred Most preferred



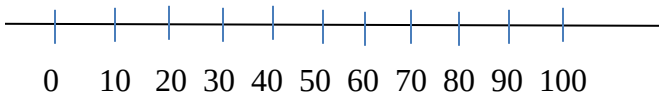
Travel Time Sign

Least preferred Most preferred



Dynamic Traffic Display Board

Least preferred Most preferred



To confirm the ranking, these three signs and board are rated. The numbers of travelers rating them are presented in the table below. It can be seen that DMS is rated overwhelmingly higher than other two. DMS's average rating is 9.94 while that for other two are 6.47 and

6.24. A statistical test was conducted to test the difference between the average ratings. The statistical test indicates that this difference in rating is significant at 95% level.

Table 7 Ratings for DMS, Travel Time Sign and Map Board

Rating	# of Responses		
	DMS	Travel Time Sign	Map Board
0	2	20	29
1	2	9	12
2	1	14	7
3	0	14	19
4	2	7	13
5	7	24	20
6	4	25	14
7	8	23	18
8	27	24	24
9	26	27	19
10	122	11	23
Average	**9.94**	**6.47**	**6.24**
STDEV	1.89	3.05	3.37

11. Please provide any suggestions to make the dynamic message signs more useful to you. More than one answer is ok.

- □ Provide more signs on highways
- □ Provide incident/congestion information earlier
- □ Provide information on congestion duration
- □ Provide information on congestion length
- □ Other, specify _____

Among the four suggestions provided by the study, the second one: Provide incident/congestion information earlier, receive the most acceptance, and the other three suggestions receive almost equal number of acceptance varying from 96 to 103.

Table 8 Suggestions to Improve Dynamic Message Signs

Suggestions	**Number of accepted**
Provide more signs on highways	96
Provide incident/congestion information earlier	139
Provide information on congestion duration	102
Provide information on congestion length	103

38 additional suggestions are received. Among these suggestions, the following observations are provided as follows.

1. Many of them suggest to provide alternative routes
2. Many of them suggest to update the information frequently
3. Many of them suggest to provide more information
4. Providing information before ramp is interesting
5. Flashing information when crash happen has been adopted in other countries, and may be worthwhile to be tested in Nevada.

Table 9 Additional Suggestions to Improve Dynamic Message Signs

Additional suggestions by travelers
1. Specific location 2. Expected time to get past the incident, maybe 3. Time of information. Accident @ 10:05 4. Advise further up of any traffic incidents and their starting points 5. POSSIBLE ALTERNATE ROUTES 6. Update frequently or it's not effective and will be ignored 7. Traffic Display Board is best. 8. more accurate reporting of location time and cleanup 9. Many times NO info is provided or provided too late 10. 3 Seconds of flashing dynamic signs data before scrolling/appearance 11. Provide information on the time of the crash so you can guage if it is probably clearing or still at its worst. Describing if lanes are blocked or if it is in the shoulder is the best info to me. 12. If possible, suggest alternate routes. 13. Provide alternate route informaiton 14. Provide alternative route that would be faster. (I realize this is nearly impossible, but it would get people moving if somehow it could be done.) 15. Inform TV /Radio earlier during early am news broadcasts 16. cycle through the information on the board faster so it can be read completey before passing

Table 9 Additional Suggestions to Improve Dynamic Message Signs (cont.)

Additional suggestions by travelers
17. Larger Signs to be seen more easily at 65mph
18. Be more accurate with info, give alternative route ideas (Airport Bypass)
19. On the Dynamic Display Board shown earlier, it wasn't clear in which lanes the traffic incident is occurring, which is why I thought it seemed less useful. If it is clear the direction (N-bound, E-bound, etc.) the incident occurs, it may be more useful because you can plan the alternate route using the map.
20. Give time when accident happened so you can judge if it just happpened or is in clean up stage
21. PLEASE work with UNLV Class Scheduling when scheduling major highway work such as the Airport Flyover especially on Tuesdays and Thursdays.
22. Information should rollover (i.e., both dynamic message and travel time)
23. Short & descriptive info, since you are driving, you don't have time to read rows of information, you must decide to make a travel adjustment within seconds
24. Provide alternative routes
25. More up to date; How about a time stamp;
26. List affected exists (e.g., Sahara to Valley View)
27. work more closely with other services, i.e., TomTom
28. Current congestion on local main streets
29. The dynamic signs are a waste of money
30. I find those signs distracting to my driving & people don't pay attention to them
31. forward information to phones
32. Combine all 3, provide the Map, Exit with incident and estimated time of travel expected. Just as you would on Google Maps.
33. that dynamic crash board looks pretty good...
34. Providing signs before entering highways
35. Be specific about which direction(s) are affected
36. time it happned and how long expected to last, never know if it is current and if we should believe
37. Provide suggested alternate route(s)
38. In case of major incidents specify suggested alternative routes with less travel time

12. In addition to using dynamic message signs and travel time signs in Questions 9 and 10, are there other ways you get traffic information when you are **on the road** for your travel? Choose any one that applies to you.

- □ Radio
- □ Map app on cell phone (e.g., Google Traffic Info)
- □ Public traveler information services (e.g., RTC traffic map, 511)
- □ Commercial traveler information services (e.g., INRIX, TomTom)

□ Social media (e.g., Twitter)
□ None
□ Other, please specify: _____

As indicated Table 10, among the five options of getting traffic information on the road, radio and Map app on cell phone are the most chosen, about half of the responses. The other three options do not have popular usage. There are some travelers who do not use any of these options to get traffic information.

Seventeen respondents provided other options (see Table 11), most of which are either examples of the options provided in the survey or not the one apply to en route condition. Two responses are about legal concern of using cell phone while driving. In the current ITS market for traveler information system, technologies are developed to announce the incident/congestion information vocally, which is a way to resolve the legal issue of using cell phone while driving.

Table 10 Survey Provided Other Ways to Get Traffic Information on the Road

Other Ways to get traffic information on the road	# of Responses
Radio	122
Map app on cell phone (e.g., Google Traffic Info)	117
Public traveler information services (e.g., RTC traffic map, 511)	13
Commercial traveler information services (e.g., INRIX, TomTom)	14
Social media (e.g., Twitter)	30
None	20

Table 11 Respondent Provided Other Ways to Get Traffic Information on the Road

1. email alerts 2. internet before leaving work or TV before leaving home. 3. More signs 4. TV: Traffic news on Ch8 5. Television app 6. Waze 7. Radio Traffic Station 8. SIrius XM Data 9. GPS in car 10. word of mouth 11. TV 12. there is no sure way in las vegas to get this information.....the radio doesn't provide 13. anything on cell phones or social media won't work if it's against the law to use them while driving 14. Traffic notification from Google Now 15. sirius traffic integrated into car 16. Cell phone used as navigation device given I would not be ticketed for such usage **17.** If phone has location services on, send a text message!

13. What is your age?
    ☐ 16-20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ 70+

The age distributed as a normal distribution where the young and senior travelers are fewer than those of middle aged. Most of the travelers are aged from 31 to 60. This distribution represents a typical driving population.

Table 12 Age Distribution

Age Category	Count
16-20	0
21-30	34
31-40	37
41-50	60
51-60	48
61-70	20
70+	1

14. What is your gender?
    ☐ Male ☐ Female ☐ Other

About 40% of the responses is male and 60% is female which can be seen from Table 13. This proportion is close to the reality perceived.

Table 13 Gender Distribution

Gender	Count	
Male	78	39%
Female	121	60.5%
Other	1	0.5%

15. What is your level of education?

□ High school or less □ High school graduate □ Some college credit
□ Associates/tech school degree □ Bachelor's degree □ Graduate degree
□ Other degree □ Prefer not to disclose

It can be seen from Table 14 that about 21% the respondents have other degree and 31% do not disclose their education, in total 50% of the respondents are known their education. It is hard to know the education distribution.

Table 14 Education Level

Education Category	Count	%
High school or less	1	0
High school graduate	20	10%
Some college credit	0	0
Associates/tech school degree	8	4%
Bachelor's degree	65	32%
Graduate degree	2	1%
Other degree	43	21%
Prefer not to disclose	63	31%

Based on the analysis of the survey data, the following observations can be made:

First, on diversion behavior, most of the travelers (80%) do want to take alternative routes to avoid congestion on freeways and more than half of the travelers (60 %) would like to use the traffic information to decide whether they want to divert to other routes. However there is significant number of travelers (about 30%) who would consider taking different routes only when they see the congestion on the road. If accurate incident/congestion information is provided, more travelers (about 10%) would divert to alternative routes. For those who do not want to take alternative route, the primary reason is that there are no convenient alternative routes in Las Vegas. Some travelers indicate that staying on freeways is still faster than taking alternative route. Familiarity to the local road is a very minor reason.

Second, most of travelers (87%) believe the traffic information provided on the DMSs is useful for their travel. They indicate that the locational information about incident/congestion is provided well, but not the information on the severity of incidents. Among the information on the congestion severity, where congestion backs up to is the most important because it is the most relevant to how much delay travelers would incur. This is confirmed by both the ranking and rating.

Third, among the three different DMS signs that present the incident information in different ways, the current one is preferred to the travel time sign and map board.

Fourth, to improve the performance of dynamic message sign, most travelers expect the signs to present incident information earlier. This suggestion is consistent with the needs for presenting spatial incident information. In addition, many of travelers suggest to provide information on alternative routes, to provide more information, to provide information before ramp, and flashing information when crash happen.

Fifth, there is a significant number of travelers (about 60%) who use other ways to obtain traveler information while they are on the road. Radio and Map app on cell phone are mostly chosen (605) by travelers to get traffic information en route. Some responses raised legal concern of using cell phone while driving. In the current ITS market for traveler information system, technologies are developed to announce the incident/congestion information vocally, which is a way to resolve the legal issue of using cell phone while driving.

Chapter 6 Conclusions and Recommendations

Conclusions

Based on the literature review, tour of FAST, data analysis of DMS operations, and survey of travelers, the following conclusions can be made:

First, provide incident information earlier. The investigation on the DMS operation indicates that more dynamic message signs should be activated to display incident information, which is coincided with the needs identified through the survey. Providing incident information earlier is to provide incident information to travelers before they run into congestion having no way to divert to alternative routes. It is not just to provide incident information at the location close to where they occur. As the progression of congestion caused by incidents, the travelers who may not be caused in congestion may become highly likely to be influenced by the congestion. This situation requires the monitoring of incident congestion closely and activating additional DMS correspondingly in a timely manner.

Second, provide more information on incident. The information on where congestion back up to, traffic flow in congestion, lane blockage, etc. are critical to determining the delay travelers would experience if they stay on freeways. By knowing the information, they can take alternative routes to avoid congestion caused by incidents.

Third, provide more reliable information on incident. It is found that the travel time information provided on the travel time signs may not be accurate at certain locations and during certain time periods.

Recommendations:

Given the information needs and operational issue using the dynamic message signs at FAST, the following recommendations are developed.

First, developing a computer aided system for using dynamic message signs in traffic management. This system would allow DMS to be activated on time and at right place. Currently, the use of DMSs in FAST is manually in nature, which is incompetent in responding to the complicated traffic condition when there are incidents. There are such computer aid systems in other TMCs, and the research on developing tools to manage traffic using computers

has been continued over many years. It is feasible to develop such a system that improves the performance of DMS in managing incidents.

It can be perceived that a hypothetical time space diagram in Figure 6 can be first generated based on historical data after the identification of an incident. The DMSs potentially to be activated can be presented on the screen. A real time time-space diagram for this incident can be generated based on the real time traffic data, overlapping over the hypothetical one. Any congestion moving close to the potential DMSs can be alerted with warning. This hypothetical diagram can also be updated based on additional information on incident, e.g., the time when additional lane blocked by emergency response vehicles, and the time when the incident is cleared.

Second, improving on the messages on incidents provided on DMS.

1. Some states like Texas and New Jersey have developed DMS manuals that specify the design and operations of DMS, particularly on displaying incident messages on intersecting freeways. By developing such a manual, any traffic control centers would have it as guidance for their managing traffic in incidents.
2. It should be investigated how to provide more incident information to travelers, particularly the locational information such as where congestion back up to. The survey results show that the map sign is not preferred, which may be caused by the way the survey was designed. More study on this should be done.
3. Based on the current size of DMS, some messages may be simplified so that more space can be used to display locational information on incidents.
4. The displayed travel time may be flashed to indicate the freeway segments that have incident occurred or have congestion impacted. The color on the displayed travel time can also be changed to represent the extent of congestion, e.g., yellow for 40 mph, pink for 20 mph, red for stop. This practice has been adopted in some cities in other countries like Singapore. Displaying different colors is not n technical issue at current time.
5. It might be worthwhile to test using bigger DMS like the one proposed to be used in the Neon project. More incident information can be displayed. Or, additional signs can be attached to the existing DMSs to display additional incident information. MUTCD should be followed in specifying the sign of the text.

Third, improving the reliability of travel time information provided on DMS. It is identified in this study that some travel time may not reflect the congestion on the freeway segments it intended to present. This might be caused by using data incorrectly or different algorithm. The algorithm may not consider the time lag for vehicles traveling from the beginning to the end of a freeway segment by which the instantaneous travel time is not accurate.

Fourth, improving the data system in incident management in FAST. It was found that the DMS activation times are entered incorrectly. It may be caused either entering the incident data or DMS data. The accuracy of data is important for investigating system performance.

Fifth, conducting a study on locating the DMSs on the Las Vegas network. DMSs should be located before the locations where incidents usually occur. In this study, the spatial distribution of incidents should be studied first, and the migration of incident locations over the years should also be looked. Whether DMSs should be relocated can be determined based on the locations identified for incidents.

Sixth, due to the legal issue, providing alternative route information is not recommended in this study.

Acknowledgement

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Appendix A

Case 2: Crash at Tropicana Avenue

This crash occurred at Tropicana Avenue on 12/5/2014 around 5:35:00 PM (see Figure A.1). It resulted in blockage of two express lanes. Only one DMS located 1.9 miles upstream the crash displayed the crash message (Table A.1). The message was displayed at 5:45 PM which is 10 minutes after crash.

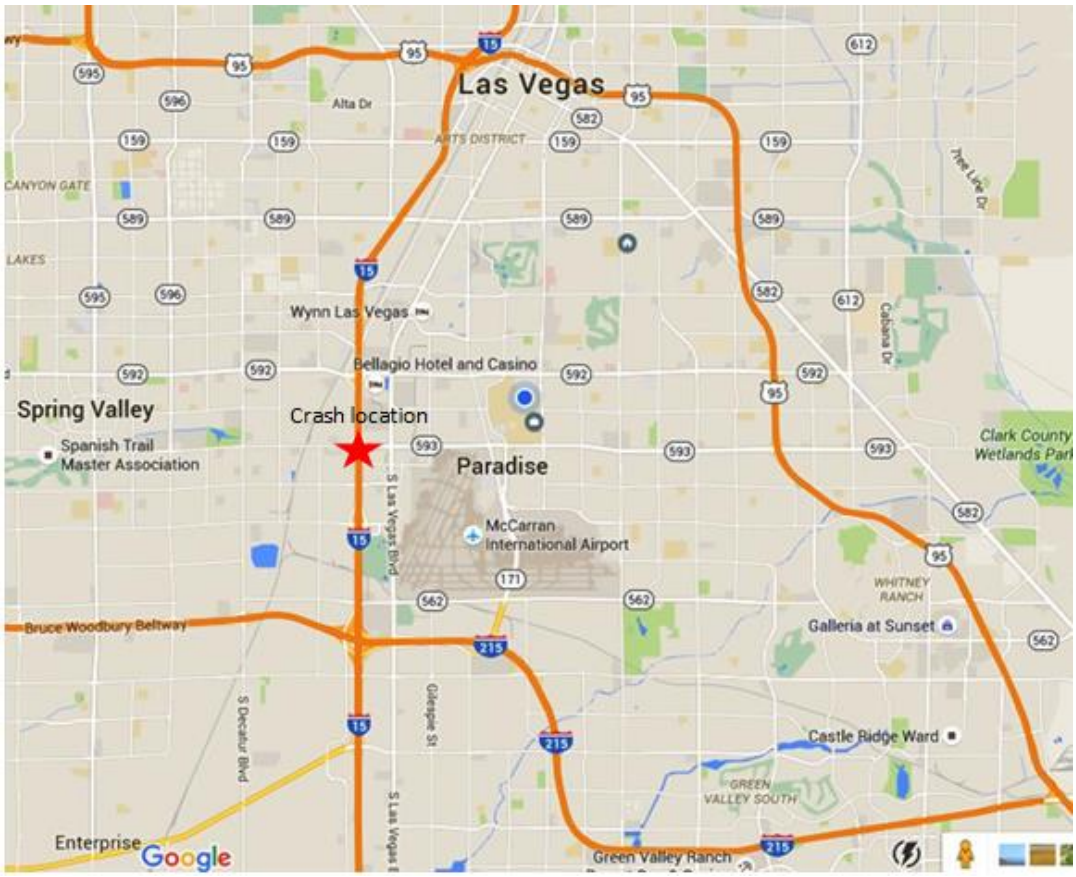


Figure A. 1 Crash Location for Case 2 on Tropicana Ave.

Table A. 1 Log File of Dynamic Message Signs for Case 2: Crash at Tropicana Ave.

DMS #	Route	DMS Location	Distance from Crash	Message Displayed
13	I-15	North of I-215	1.9	ACCIDENT/ PAST TROPICANA / EXP LANES CLOSED /
1	I-15	North of Blue diamond	3.9	FLAMINGO 11 /US-95 19/ CRAIG 25/
80	I-15	North of St. Rose Pkwy	8.9	6//15//23
71	I-215	West of Eastern Ave.	6.9	5 / 11 / 13 /
69	I-215	East of Green Valley Pkwy	9.9	8 / 15 / 16 /

The traffic data (see Figure A.2) revealed that there was no significant speed reduction as a result of the incident. Considering the first five minutes after crash for a distance of 5.5 miles upstream, the minimum speed was about 53 mph for both I-15 and I-215. The minimum average speed on the freeways (53 mph) was observed to be higher than the maximum posted speed limit on the major arterials. Due to insignificant travel speed reduction observed, the travel time is also assumed to be significantly low thus there is no need of consideration of other alternative routes.

Location	South Russell	North I-215	South Warm Spring	North Blue Diamond	South Blue Diamond	North Wigwam Ave	South Ford Ave	South Raven Ave	At Serene Ave
Distance	**1.28**	**2.49**	**3.54**	**3.87**	**4.2**	**4.55**	**4.85**	**5.23**	**5.58**
Time									
17:36	69.0	53.3	53.3	66.8	73.3	68.0	79.3	61.5	69.5
17:37	69.0	54.3	54.3	66.3	73.7	68.3	80.7	62.8	69.5
17:38	71.0	54.3	54.3	66.3	75.3	68.0	82.0	62.5	68.0
17:39	68.0	53.3	53.3	67.3	75.7	69.3	81.7	60.8	69.5
17:40	69.0	54.0	54.0	67.0	74.7	70.3	82.0	60.3	68.3
17:41	72.0	54.3	54.3	67.5	74.3	69.7	83.3	60.3	68.3

Figure A. 2 Time-Space Diagram for Case 2 (South of Tropicana Ave.)

Case 3: Crash located South of Sahara Avenue

Crash involved in this case is the one occurred on 12/5/2014 at 17:46. This crash occurred south of Sahara Avenue. Among the six lanes available at this location, only one center lane was

blocked. The incident lasted for 5 minutes before being cleared. Two DMS located at a distance of 0.6 and 2.45 displayed the crash message one minute after crash occurrence. At the same moment, DMS number 13 which is located 4.75 miles upstream was displaying the previous crash that occurred at Tropicana Avenue (Table 12).

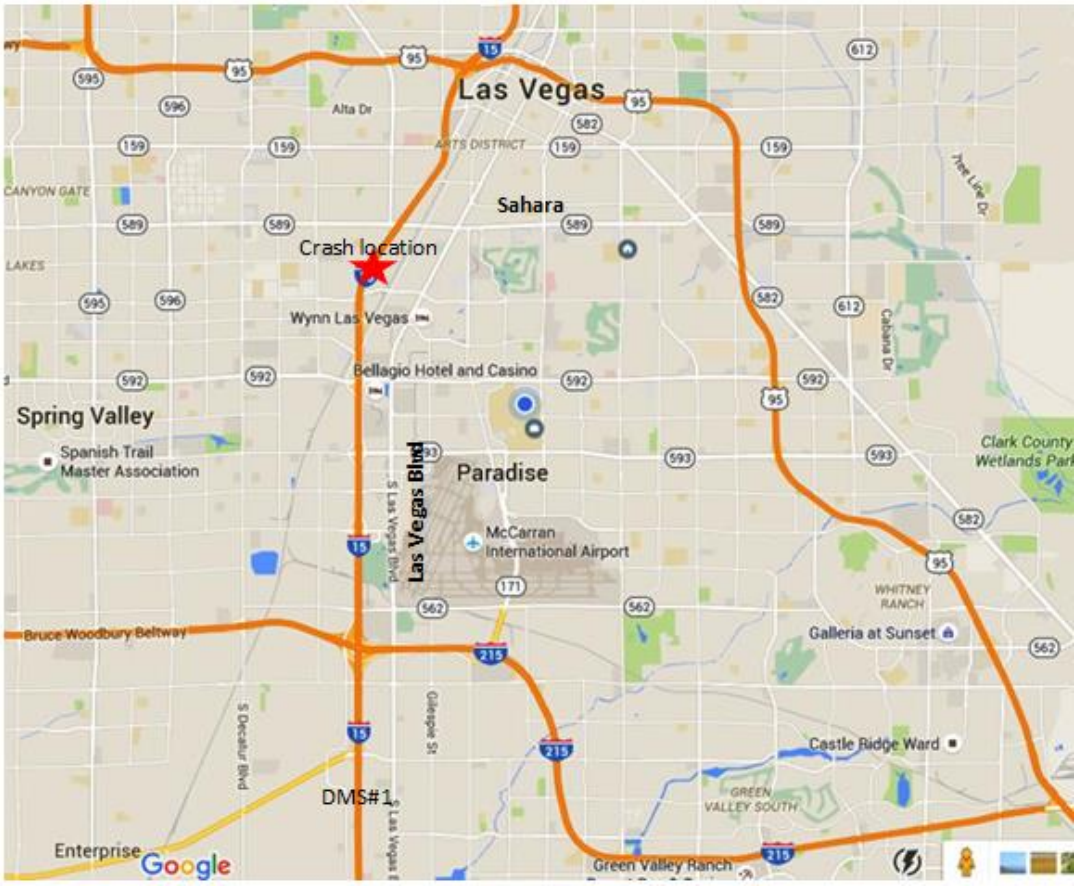


Figure A. 3 Crash location for Case 2: South of Sahara on 12/5/2014 at 5:46:00 PM

Table A. 2 Log file of Dynamic Message Signs for Case 3: Crash at South of Sahara Ave.

DMS #	Route	DMS location	Distance from Crash	Message displayed
16	I-15	South of Sahara	0.6	CRASH SAHARA / RIGHT LANES / BLOCKED /
2	I-15	North of Tropicana	2.45	CRASH SAHARA / RIGHT LANES / BLOCKED /
13	I-15	North of I-215	4.75	ACCIDENT/ PAST TROPICANA / EXP LANES CLOSED /
1		North of Blue diamond	6.75	FLAMINGO 11 / US-95 19/ CRAIG 25
80	I-15	North of St Rose Pkwy	11.75	6//15//23
71	I-215	West of Eastern Ave	9.75	6 / 13 / 13 /
69	I-215	East of Green Valley Pkwy	12.75	8 / 17 / 17 /

Location	South of Sahara	North of Desert Inn	South of Desert Inn	South of Spring Mtn	North of Flamingo	South of Flamingo	South of Harmon Ave
Distance	**0**	**0.43**	**0.71**	**0.98**	**1.59**	**2.02**	**2.24**
Time							
17:47	23.3	24.2	68.0	57.0	67.7	65.8	54.2
17:48	25.8	26.5	70.0	58.3	68.3	68.0	52.8
17:49	23.3	44.8	71.8	53.0	66.0	66.5	54.4
17:50	27.7	41.7	60.0	70.3	58.0	65.0	61.6
17:51	27.7	62.0	70.0	63.7	68.3	65.8	50.0
17:52	21.7	65.2	70.8	62.7	63.0	62.5	49.2
17:53	21.0	64.5	72.0	62.7	65.0	64.8	54.6
17:54	31.0	65.8	70.5	61.3	69.0	67.3	50.6
17:55	38.5	67.2	70.0	65.0	66.3	67.0	54.2
17:56	52.0	69.3	68.5	67.7	66.7	63.0	53.4
18:01	66.5	67.8	70.5	56.3	64.3	64.3	52.8
18:06	67.0	89.0	101.8	59.0	127.0	127.0	52.6

Figure A. 4 Speed Time-Space Diagram for Case 3: South of Sahara

Crash impact in terms of speed reduction was observed for the first eight minutes at the distance of approximately 0.5 miles from the crash location (see Figure A.4). For this case, the DMSs appear to play great role to disseminate crash information. First, the crash information was displayed on time (just one minute after crash). Secondly, the crash messages were displayed at a distance of 2.45 miles upstream the crash location thus the large number of the road users were notified regarding the crash.

Case 4: Crash at Tropicana Avenue

This case encompasses a crash dated 12/6/2014 occurred at Tropicana Avenue around 1:14:00 PM. This crash resulted into one lane closure at the section with 3 lanes. No delay in the DMS activation was observed as the first DMSs located 1.9 miles upstream was activated at 1:14:00 PM while the second which is located 3.9 miles upstream was activated at 1:15:00 PM (see Table A.3). No significant traffic delay was observed since the speed reduction was not of the noticeable amount as shown in Figure A.6.

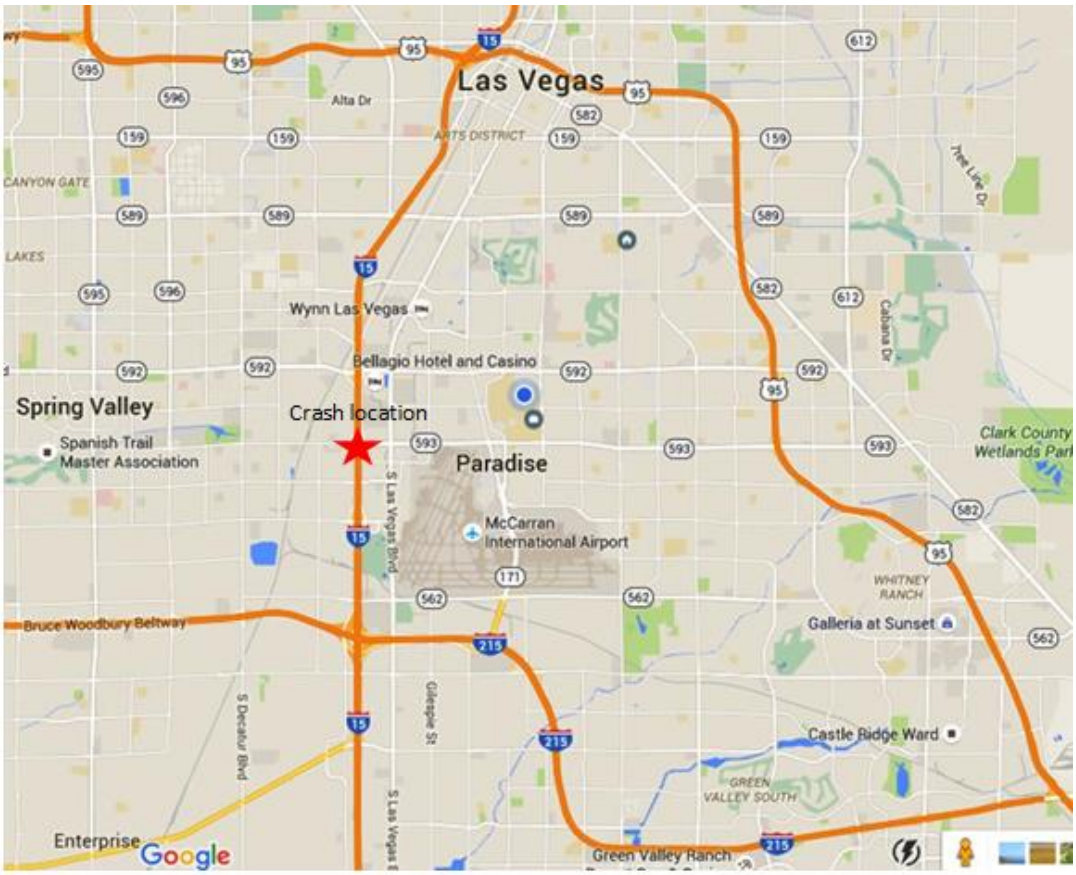


Figure A. 5 Crash location for Case 4: Tropicana Avenue on 12/6/2014 at 1:14:00 PM

Table A. 3 Log File of Dynamic Message Signs for Case 4: Crash at Tropicana Ave.

DMS #	Route	DMS location	Distance from Crash	Message displayed
13	I-15	North of I-215	1.9	CRASH/TROPICANA /RIGHT LANES CLOSED /
1	I-15	North of Blue diamond	3.9	CRASH I-15/TROPICANA /RIGHT LANES CLOSED /
80	I-15	North of St Rose Pkwy	8.9	6//9//15
71	I-215	West of Eastern Ave	6.9	4 / 7 / 8 /
69	I-215	East of Green Valley	9.9	7 / 11 / 11 /

Location	South of Russell	North of I-215	South of Warm	North of Blue	South of Blue	North of Wigwa	South of Ford	South of Raven	At Serene Ave	South of Silverado
Distance f	0.9	2.1	3.2	3.5	3.8	4.2	4.5	4.9	5.2	6.1
Time										
13:14	77.0	59.3	62.9	66.5	77.0	70.0	78.0	65.3	70.3	72.3
13:15	73.0	89.0	78.1	67.3	77.7	69.0	76.7	63.8	67.5	71.3
13:17	77.0	55.3	61.0	66.8	77.0	72.3	81.0	59.8	66.8	71.5
13:19	77.0	53.3	59.5	65.8	78.0	70.7	77.7	62.0	65.3	73.0
13:24	75.0	82.7	74.7	66.8	77.7	67.7	79.3	65.3	68.8	73.0
13:29	76.0	61.7	63.3	65.0	78.7	68.7	77.7	62.0	67.8	73.3
13:34	71.0	58.0	61.6	65.3	76.7	69.3	77.3	63.5	67.8	72.5
13:39	68.0	57.0	61.1	65.3	78.3	67.3	75.7	57.3	68.3	73.0
13:44	75.0	58.3	62.4	66.5	77.7	68.7	80.7	62.0	67.5	74.5
13:49	73.0	121.7	94.0	66.3	76.7	70.3	77.7	63.0	68.3	73.0
13:54	70.0	62.7	64.0	65.3	75.0	65.3	77.7	61.3	70.5	72.0
13:59	74.0	57.3	71.5	85.8	82.0	66.3	80.3	66.0	68.8	74.3
14:04	75.0	57.0	62.4	67.8	79.7	69.3	79.3	65.5	69.5	73.8
14:09	70.0	56.7	61.7	66.8	79.3	67.3	80.7	66.5	69.8	73.0

Figure A. 6 Time-Space Diagram for Case 4: South of Tropicana Ave.

Case 5: Crash located South of Charleston

This crash occurred on 12/10/2014 around 8:22:00 PM south of Charleston Boulevard. It blocked a right lane at a section with five lanes and took 78 minutes to be cleared. Two DMSs upstream the crash location displayed the crash messages (see Table A.4). However, the crash time of the activation time may be wrongly recorded as it can be read from the data that the DMSs activation times were 8:20PM and 8:21PM respectively which were the times before the crash occurrence.

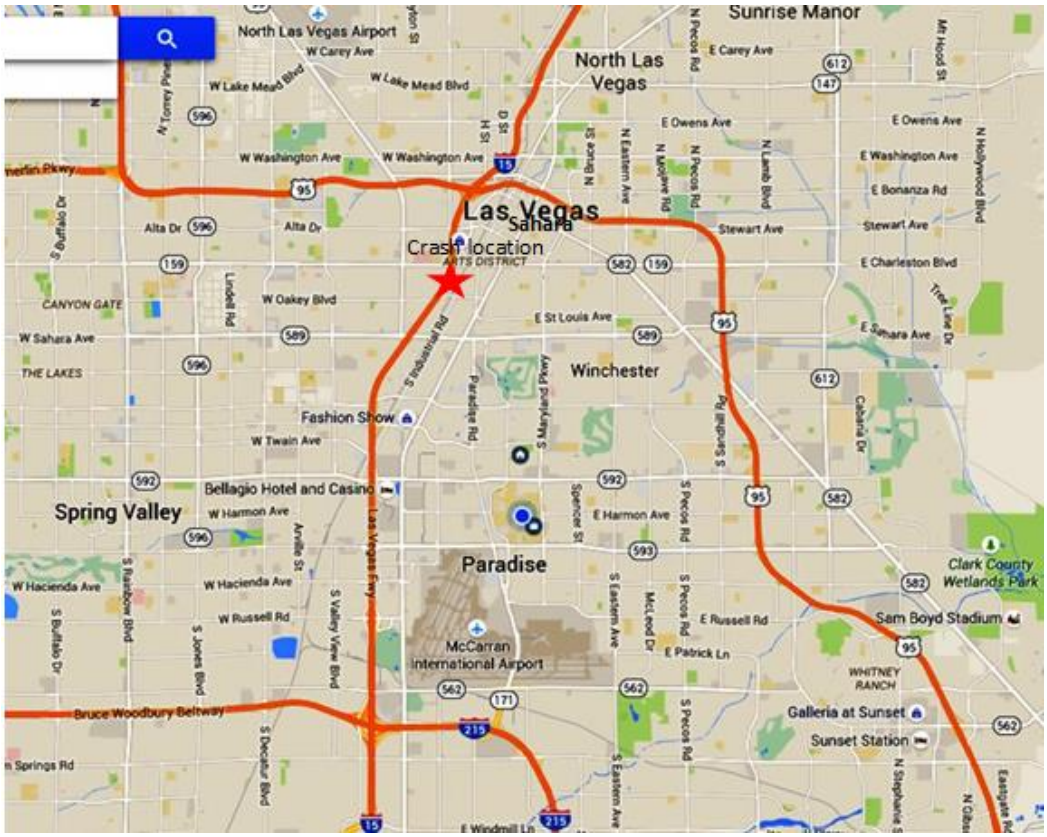


Figure A. 7 Crash Locations for Case 5: South of Charleston Ave. on 12/10/2014 at 8:22:00 PM

Table A. 4 Log File of Dynamic Message Signs for Case 5: South of Charleston Crash

DMS #	Route	DMS location	Distance from Crash	Message displayed
3	I-15	North of Sahara	0.45	ACCIDENT / RIGHT LANE/ BLOCKED
16	I-15	South of Sahara	1.80	ACCIDENT /AT CHARLESTON/ RIGHT LANE BLOCKED
2	I-15	North of Tropicana	3.65	US-95 7 /LAKE MEAD BLVD 9 / CRAIG RD 13 /
13	I-15	North of I-215	5.95	SPRING MT 5 /US-95 11 /CRAIG RD 16 /
1	I-15	South of Blue Diamond	7.95	FLAMINGO 7 /US-95 13 / CRAIG 19 /
80	I-15	North of St Rose Pkwy	12.95	6//9//17
71	I-215	West of Eastern Ave	10.95	4 / 7 / 8 /
69	I-215	East of Green Valley Pkwy	13.95	7 / 11 / 11 /

The incident resulted in reduction of traffic speed, the minimum average speed observed was 9.2 mph at a distance of 0.8 miles and 15 minutes form the time of crash. The congestion effect lasted for about 80 minutes and was extended to a distance of 1.4 miles from the incident location as shown in Figure A.8.

Location	South of Oakey	North of Sahara	South of Sahara	South of Sahara	North of Desert	South of Desert	South of Spring	North of Flamingo	South of Flamingo	South of Harmon	North of Tropicana	South of Russell
Distance	0.4	0.8	1.2	1.4	1.8	2.1	2.4	3.0	3.4	3.6	3.9	5.3
Time												
20:22	60.2	30.6	59.7	65.5	69.7	75.0	60.7	62.3	68.3	66.4	89.3	74.0
20:27	12.6	10.5	59.5	63.2	69.0	72.8	58.7	64.7	69.5	70.2	74.0	75.0
20:32	16.2	34.8	39.2	62.5	70.7	71.5	62.3	68.0	70.8	68.6	73.3	72.0
20:37	16.8	9.2	28.5	49.7	71.2	73.0	63.3	68.0	68.0	68.0	72.3	68.0
20:42	15.6	17.8	30.0	59.7	69.3	70.5	61.3	67.0	69.8	69.2	76.0	73.0
20:47	13.4	16.8	34.2	53.7	66.7	70.0	72.7	58.7	66.0	68.2	65.5	59.0
20:52	31.8	18.6	29.8	32.5	61.2	68.3	57.3	65.3	64.0	56.0	58.5	76.0
20:57	15.0	13.4	32.2	58.0	66.8	69.5	65.3	70.3	69.0	68.8	76.8	68.0
21:02	14.2	13.0	51.5	62.2	68.5	72.3	65.0	66.7	69.8	66.8	75.0	69.0
21:07	14.6	12.8	48.7	60.5	68.3	70.5	63.0	68.3	67.5	68.4	71.3	72.0
21:12	11.8	18.6	29.8	32.5	61.2	26.0	26.0	36.7	50.8	63.0	70.0	66.0
21:17	12.4	10.6	39.5	51.8	69.3	76.8	61.3	69.7	71.5	64.6	74.8	74.0
21:22	14.4	13.8	34.0	54.2	68.5	73.8	64.7	67.0	69.8	66.6	88.0	74.0
21:27	15.2	9.4	33.3	59.0	66.7	74.5	50.3	68.0	69.0	62.6	73.0	76.0
21:32	23.0	39.0	36.3	60.3	66.0	71.3	62.3	64.7	67.3	68.0	78.3	76.0
21:37	29.8	59.0	62.8	66.2	69.2	73.8	57.3	68.0	70.0	68.8	74.3	72.0
21:42	61.6	18.6	29.8	32.5	61.2	68.3	57.3	65.3	64.0	56.0	58.5	74.0
21:47	79.8	69.6	63.8	68.3	71.3	76.8	62.0	70.0	73.3	69.8	77.5	75.0
21:52	63.0	66.6	65.5	66.7	70.8	70.8	61.3	68.0	73.0	69.2	76.8	74.0

Figure A. 8 Time-Space Speed Diagram for the Crash 5: South of Charleston

The travel times for the vehicles using the highways I-15 and I-215 were calculated and presented in Table A.5. The same detour routes presented in Figures 3 and 7 could be used. The travel time for the vehicles that could use the detour routes were calculated and presented (Table A.5). The equivalent travel time for the vehicles using the highways and the other using detour routes to reach the same destination (Charleston and I-15 interchange) could not be computed due to lack of the exact time that the DMSs were activated.

Table A. 5 Travel Times on Detour Routes

Detour locations	Spring Mtn	Flamingo	Tropicana	Russell
Travel time through detours routes (min)	5.9	6.8	8.2	9.8

Case 6: Crash located at Sahara Avenue

This crash occurred on 12/15/2014 around 2:46:00 PM at the I-15 and Sahara interchange. Two DMSs upstream the crash location displayed the crash messages (Table A.6). The crash resulted into blockage the left lane at a section with five lanes and it lasted for 51 minutes.

Table A. 6 Log File of Dynamic Message Signs for Crash at Sahara Ave.

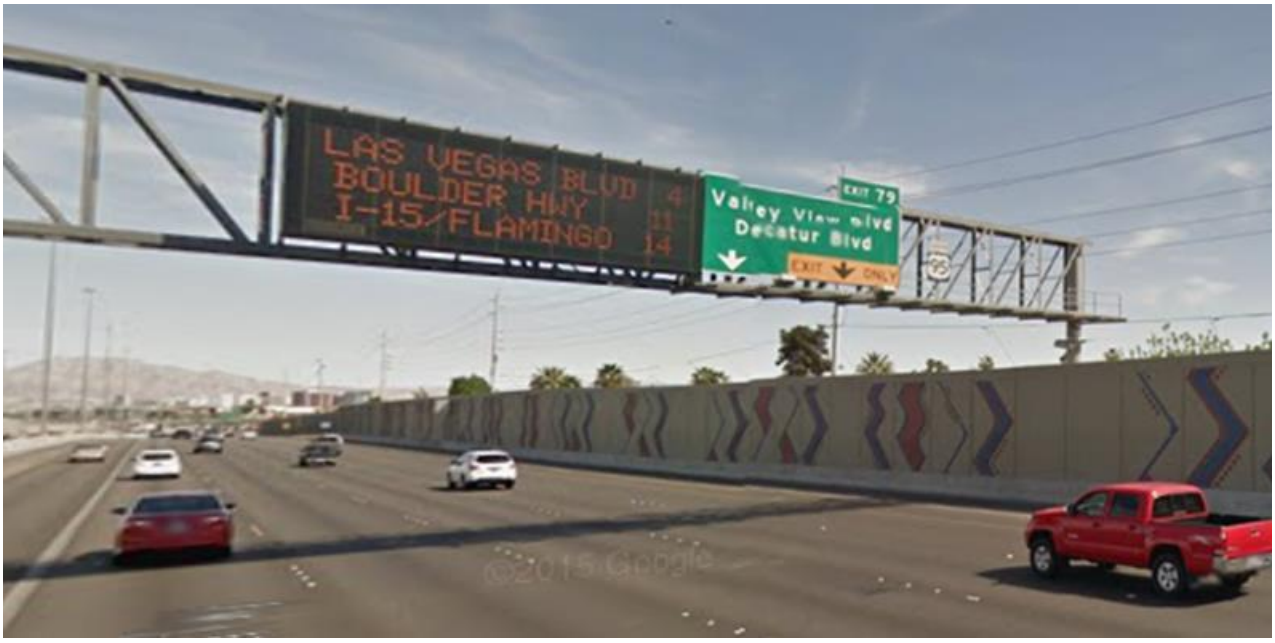
DMS #	Route	DMS Location	Distance from Crash	Message Displayed
16	I-15	South of Sahara	0.85	ACCIDENT / AT SAHARA/ LEFT LANE CLOSED /
2	I-15	North of Tropicana	2.7	ACCIDENT / AT SAHARA/ LEFT LANE CLOSED /
13	I-15	North of I-215	5	SPRING MT 5 / US-95 11 / CRAIG RD 17 /
1	I-15	South of Blue Diamond	7	FLAMINGO 7 / US-95 14 / CRAIG 19 /
80	I-15	North of St Rose Pkwy	12	6//9//17
71	I-215	West of Eastern Ave	10	4 / 7 / 7 /
69	I-215	East of Green Valley Pkwy	13	7 / 11 / 11 /

The data pertaining speed reduction which could enable the estimation of the travel times for the freeway and the alternative routes were not available.

Appendix B Survey to Travelers

Survey for Travelers in the Las Vegas Metropolitan Area

We at the University of Nevada, Las Vegas are evaluating the performance of Dynamic Message Signs (see the picture below) in managing highway incident and congestion in the Las Vegas metropolitan area. This study is supported by the Nevada Department of Transportation. To get your opinions of the dynamic message sign, we develop a survey which can be found in https://unlv.co1.qualtrics.com/SE/?SID=SV_5iNRP8xjQMTEBNP. Please answer the questions in the survey as completely as possible. Your time in completing the survey is highly appreciated.



All information gathered from this survey is kept confidential. No reference will be made in written or oral materials that could link you to this study. If you have any questions regarding this survey please contact the PI, Dr. Hualiang (Harry) Teng, phone 702-895-4940, email: hualiang.teng@unlv.edu.

For questions regarding the rights of research subjects, complaints or comments on the manner in which the study is being conducted, you may contact the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.

Your participation in this study is voluntary and you will not be compensated for your time. You are encouraged to ask questions about this study at the beginning or any time during the research study. You may withdraw at any time.

Participant Consent:
I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

☐ I do not agree

□ I agree

Survey Questionnaire

16. In what area do you live?
    Your zip code: _____

17. How frequently do you use highways as opposed to city streets in Las Vegas?
    □ Once or more than once a day □ Once a week □ Less than once a week

18. When you run into congestion, do you take alternative routes?
    □ Yes □ No

19. If your answer to Question 3 is "No", the reasons for not taking alternative routes are:
    □ I am not familiar with the highways and streets in Las Vegas.
    □ There are no convenient alternative routes in Las Vegas.
    □ Others, specify _____

20. If your answer to Question 3 is "Yes", do you take an alternative route only when you see slow traffic, regardless of the messages displayed on the dynamic message sign?
    □ Yes □ No □ Not sure

21. Would you take an alternative route if you are provided with accurate information about incident/congestion by the dynamic message signs?
    □ Yes □ No □ Not sure

22. Do you think the incident/congestion information on the dynamic message signs in the Las Vegas area is useful for your travel?
    □ Yes □ No □ Not sure

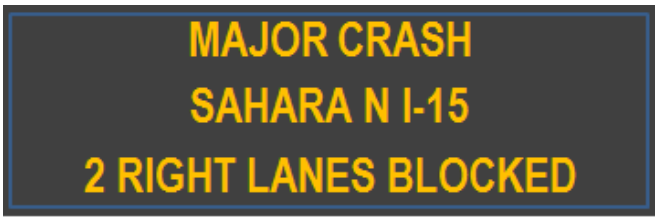
23. Is the information on the dynamic message signs clear about the location and severity of incident and congestion?

Location (e.g., crash at Sahara Ave. on N I-15)	□ Yes	□ No	□ Not sure
Severity (e.g., injury, fatality)	□ Yes	□ No	□ Not sure
Severity (e.g., blocked two lane)	□ Yes	□ No	□ Not sure
Severity (e.g., last half hour already)	□ Yes	□ No	□ Not sure
Severity (back up to Blue Diamond)	□ Yes	□ No	□ Not sure

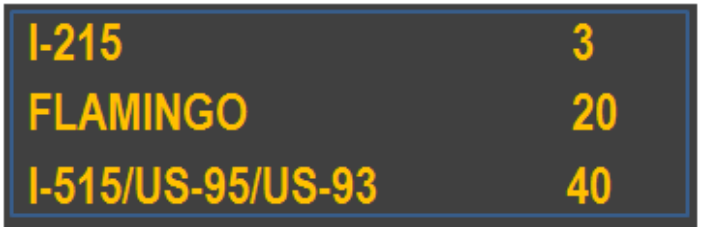
For the following **Questions 9-10**, please give us your opinions.

24. If you are driving on I-215 to the West at Eastern Avenue, and there is a crash at Sahara Avenue on I-15 Northbound in the route you plan to travel, which of the following three signs best communicate the traffic congestion caused by the crash and possible alternative routes?

    1 = the best, 2 = the second best, and 3 = the third best.



Dynamic Message Sign



Travel Time Sign

Dynamic Traffic Display Board (red shows congested area)

Sign Type	Rank
Dynamic Message Sign	
Travel Time Sign	
Dynamic Traffic Display Board	

Which of these three signs in the previous question do you prefer? Please mark your rating on the scales below.

Dynamic Message Sign

Least preferred Most preferred

0 10 20 30 40 50 60 70 80 90 100

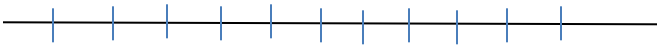
Travel Time Sign

Least preferred Most preferred

0 10 20 30 40 50 60 70 80 90 100

Dynamic Traffic Display Board

Least preferred Most preferred



0 10 20 30 40 50 60 70 80 90 100

25. Please provide any suggestions to make the dynamic message signs more useful to you. More than one answer is ok.

□ Provide more signs on highways
□ Provide incident/congestion information earlier
□ Provide information on congestion duration
□ Provide information on congestion length
□ Other, specify _____

26. In addition using dynamic message signs and travel time signs in Questions 9 and 10, are there other ways you get traffic information when you are **on the road** for your travel? Choose any one that applies to you.

□ Radio
□ Map app on cell phone (e.g., Google Traffic Info)
□ Public traveler information services (e.g., RTC traffic map, 511)
□ Commercial traveler information services (e.g., INRIX, TomTom)
□ Social media (e.g., Twitter)

□ None

□ Other, please specify: _____

27. What is your age?

□ 16-20 □ 21-30 □ 31-40 □ 41-50 □ 51-60 □ 61-70 □ 70+

28. What is your gender?

□ Male □ Female □ Other

29. What is your level of education?

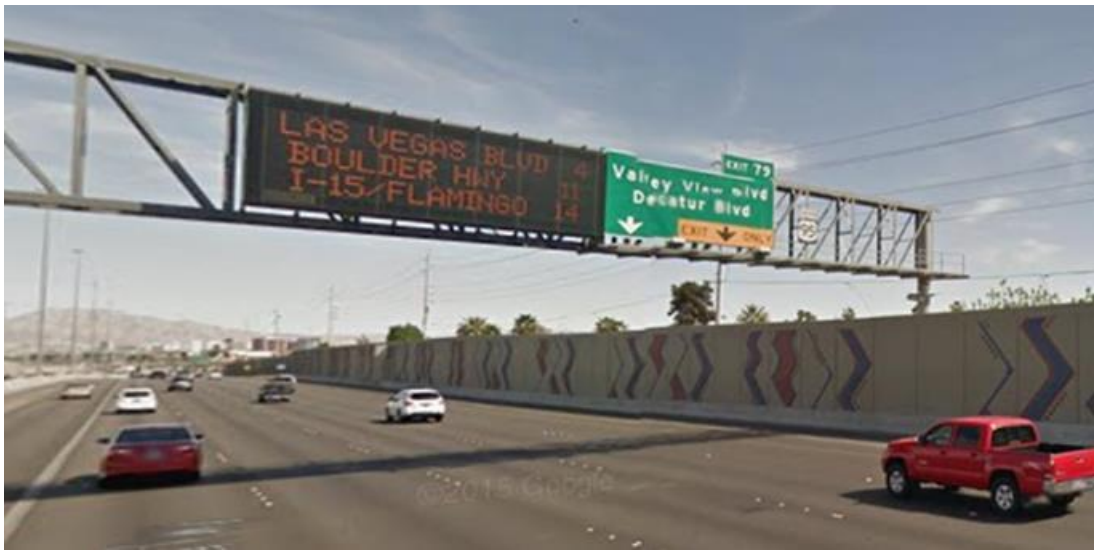
□ High school or less □ High school graduate □ Some college credit
□ Associates/tech school degree □ Bachelor's degree □ Graduate degree
□ Other degree □ Prefer not to disclose

Thank you for helping us with this survey!

Appendix C Survey to Truckers

Survey for the Truckers

We at the University of Nevada, Las Vegas are accessing the performance of dynamic message signs (see figure below) in managing highway incident and congestion in the Las Vegas area. Assuming you drive through the Las Vegas area, we would like to know how the dynamic message signs in the Las Vegas area help you in selecting various routes. Thus, we develop this survey to solicit your inputs which can be found from this web link: https://unlv.co1.qualtrics.com/SE/?SID=SV_4I2EPkXo1PX2bQh. To help you answer the survey questions, we have provided a Las Vegas Metropolitan area map on the next page for your reference. Please answer the questions in the survey as completely as possible. Your time in completing the survey is highly appreciated.



Dynamic Message Sign in Las Vegas, Nevada

All information gathered from this survey is kept confidential. No reference will be made in written or oral materials that could link you to this study. If you have any questions regarding this survey, please contact the PI, Dr. Hualiang (Harry) Teng, phone 702-895-4940, email: hualiang.teng@unlv.edu.

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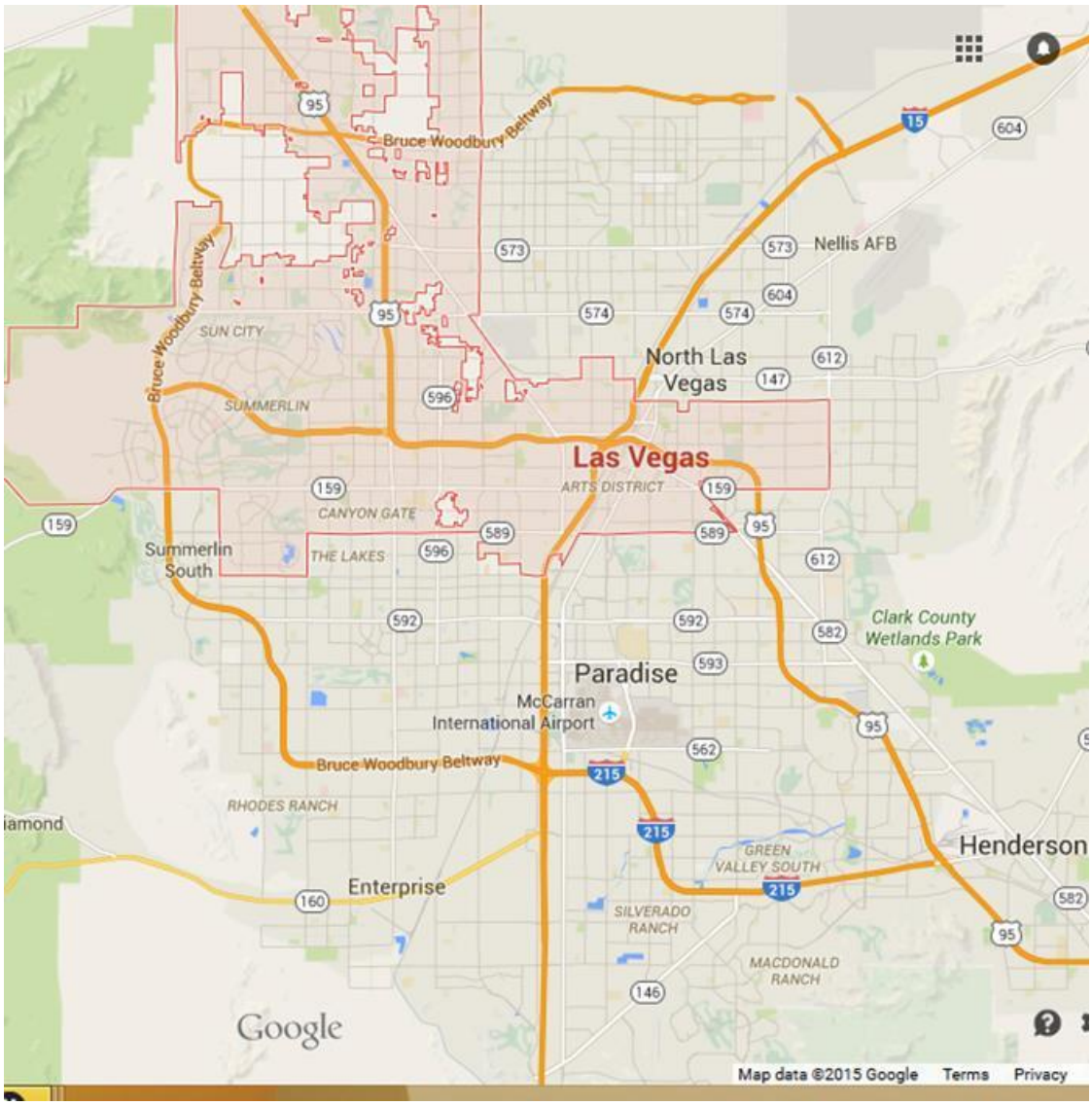
Your participation in this study is voluntary and you will not be compensated for your time. You are encouraged to ask questions about this study at the beginning or any time during the research study. You may withdraw at any time.

Participant Consent:
I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

☐ I do not agree

 I agree



Las Vegas Metropolitan Area

Survey Questionnaire

30. Are the cargos of your business or logistics time sensitive?
    □ Yes □ No

31. Do you need permission from your company central dispatch to change your trip route when you run into incident/congestion?
    □ Yes □ No

32. Have you ever received permission from your central dispatch to change routes **after** you passed the point of changing a route?
    □ Yes □ No □ Not sure

33. How frequently do you drive highways in Las Vegas?
    □ Once or more than once a day □ Once a week □ Less than once a week

34. When you run into congestion, do you take alternative routes?
    □ Yes □ No

35. If your answer to Question 5 is "No", the reasons for not taking alternative routes are (more than one answer is ok):
    □ I am not familiar with the highways and streets in Las Vegas.
    □ There are no convenient alternative routes in Las Vegas.
    □ Others, specify _____

36. If your answer to Question 3 is "Yes", do you take alternative routes only when you see slow traffic, regardless of the messages displayed on the dynamic message sign?
    □ Yes □ No □ Not sure

37. Do you think the incident/congestion information on the dynamic message signs in the Las Vegas area is useful?
    □ Yes □ No □ Not sure

38. Have you encountered a situation where you may have taken a different route if you saw the incident/congestion information on the dynamic message sign **earlier**?
    □ Yes □ No □ Not sure

39. Would you use different routes like I-215 to bypass congestion on I-15 or US 95 if you are provided incident/congestion information on the dynamic message signs in time?

☐ Yes ☐ No

If not, why? More than one answer is ok.

☐ Do not know alternative routes

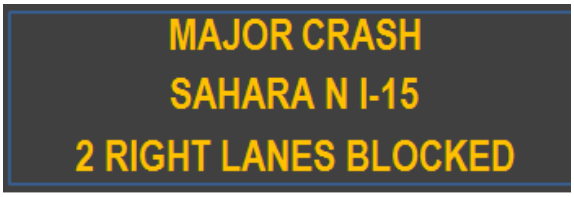
☐ Do not know the traffic on alternative routes

☐ Others, please specify: _____

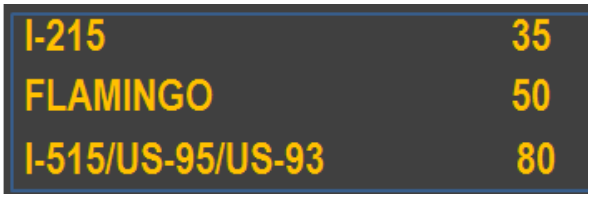
For the following Questions 11-12, please give us your opinions.

40. If you are driving on I-15 northbound to Utah before Primm, Nevada and a crash occurred at Sahara Avenue on Northbound I-15, which of the following three signs best presents the traffic congestion caused by the crash and possible alternative routes?

1 = the best, 2 = the second best, and 3 = the third best



Dynamic Message Sign



Travel Time Sign

Dynamic Traffic Display Board

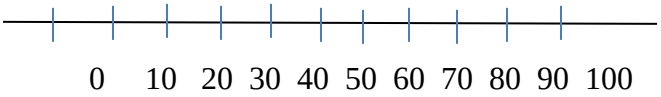
Sign Type	Rank
Dynamic Message Sign	

Travel Time Sign	
Dynamic Traffic Display Board	

41. Which of these three signs in the previous question do you prefer? Please mark your rating on the scales below.

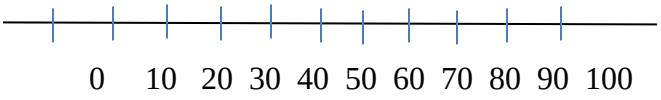
Dynamic Message Sign

Least preferred Most preferred



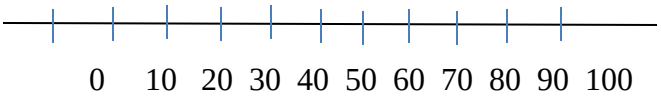
Travel Time Sign

Least preferred Most preferred



Dynamic Traffic Display Board

Least preferred Most preferred



42. Please provide any suggestions to make the dynamic message signs useful to you

- □ Provide more signs on highways
- □ Provide incident/congestion information earlier
- □ Provide information on congestion duration
- □ Provide information on how far congestion back up to
- □ Others, specify _____

43. In addition using dynamic message signs and travel time signs in Questions 11 and 12, are there other ways you get traffic information when you are **on the road** for your travel? Choose any that apply to you.

- □ Radio
- □ Map app on cell phone (e.g., Google Traffic Info)

□ Public traveler information services (e.g., RTC traffic map, 511)
□ Commercial traveler information services (e.g., INRIX, TomTom)
□ Social media (e.g., Twitter)
□ None
□ Other, please specify: _____

44. What is your age?
□ 16-19 □ 20-30 □ 31-40 □ 41-50 □ 51-60 □ 61-70 □ 70+

45. What is your gender?
□ Male □ Female □ Other

46. What is your level of education?

□ High school or less □ High school graduate □ Some college credit
□ Associates/tech school degree □ Bachelor's degree □ Graduate degree
□ Other degree □ Prefer not to disclose

Thank you for helping us with this survey.

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Carson City, Nevada 89712