ITS Heartland Competition

Travel Time Reliability of I-495 and ITS Solutions

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Abstract

I-495 (from intersection I-66 to I-95) is an important freeway spanning Virginia and Maryland. This paper begins with a literature review of travel time reliability and Intelligent Transportation Systems solutions to congestion. Then congestion measures and speed changes occurring from April to June on I-495 were analyzed. The busiest day on the freeway in both directions for a week are showed by a buffer index. The results verify that I-495 has significant congestion during the peak hours from 15:00 to 19:00. The degree of this congestion has been increasing at a significant rate. It is recommended to invest on more DMS (Dynamic Message Signs) to decrease congestion. This paper introduces the function and structure of DMS. Based on the analysis of the multiple segments' congestion and incidents locations, DMS are recommended to be installed prior the Exit 9-13, Exit 34-36 in clockwise direction, and Exit 13in a counterclockwise direction. In addition, DMS should to be installed avoiding the Exit 31, where there is high frequency of traffic incidents.

Keywords: Congestion, Travel time reliability, Dynamic Message Signs, DMS.

Introduction

I-495 (Capital Beltway) is a significantly congested corridor, since it surrounds Washington, D.C. which ranks either first or second amongst all United States congested cities. According to a study which listed the worst highway bottlenecks in the nation in 2004, two intersections of I-495 are ranked within the top 24*(1)*. Current traffic exceeds 200,000 vehicles per day on some sections and is projected to increase to about 250,000 vehicles per day by 2030 *(2)*. Therefore, it is extremely essential to evaluate the current transportation situation of the I-495 and propose efficient solutions.

This study focuses on the I-495 segment between the intersection of I-66 in Virginia and the I-95 in Maryland (Figure 1). By analyzing the measured travel time and the changes occurring from April to June 2012, the reliability of this freeway was evaluated and solutions to decrease congestion were recommended. In this paper, Dynamic Message Signs are the Intelligent Transportation System (ITS) solution proposed to solve the problem of congestion.

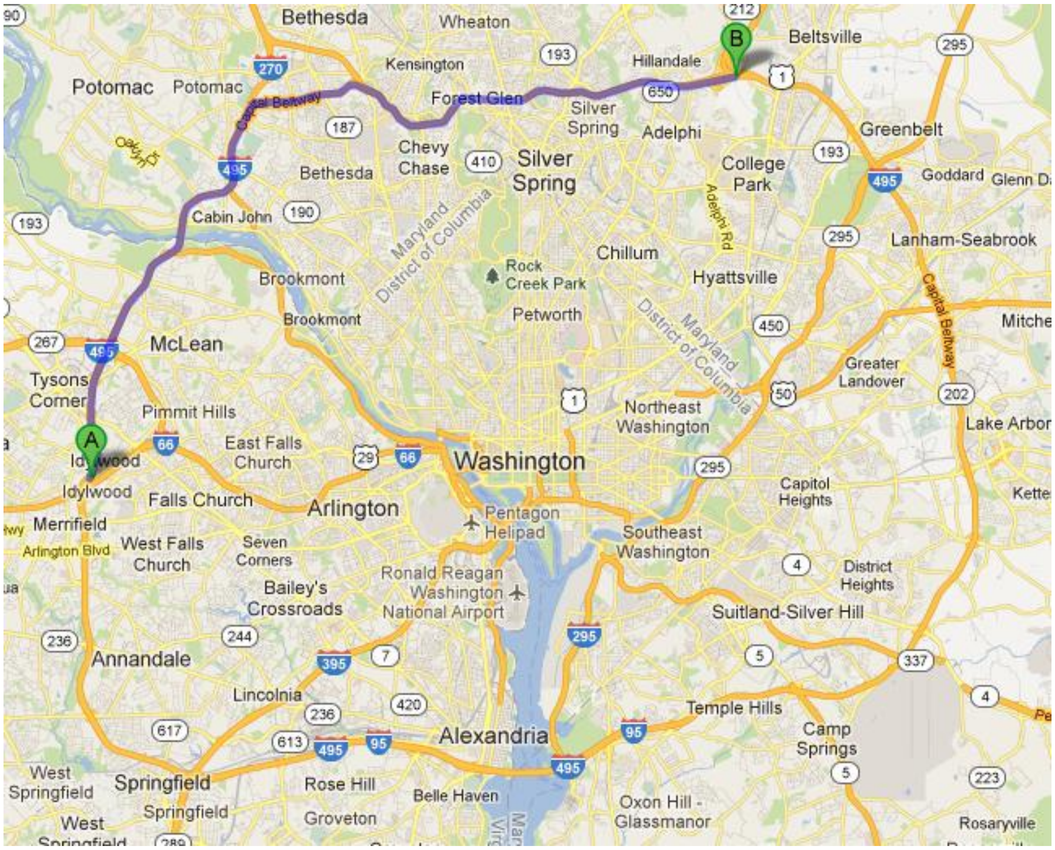


Figure 1: Study Segment *(Source: Google Map)*

Literature Review

Travel time reliability

Travel time reliability is a measure of the amount of congestion users of the transportation system experience at a given time *(3)*. Travel time reliability is an extremely important performance measurement of congestion and planning ITS planning and operations. Based on the travel reliability, prioritizing improvements can be easily and effectively determined.

The Federal Highway Administration (FHWA) has used several measures to quantify travel time reliability *(4)*:

a. The 90th or the 95th percentile travel time

b. The travel time index

c. The buffer index

d. The planning time index

e. Frequency that congestion exceeds some expected threshold

One case study of travel time reliability was performed in Portland, Oregon *(5)*. It used the buffer index as the primary measure. The goal of the Portland freeway reliability study was to evaluate and compare all major freeway segments according to travel time reliability. The researcher divided the freeway into 11 segments. The buffer index of different segments in different year (2004 to 2007) at peak hours was compared. The author also picked the individual segment out, using line charts to show the four year's buffer index at different times of a day. It was concluded that all the freeway segments have higher buffer index in PM peak hours than in AM peak. And many of segments had very high spikes during specific years at specific times, especially in 2007. The result of the study showed that travel time reliability is an important measure of the health of a transportation system. And it can help to prioritize system improvements in a more decisive way *(5)*.

Dynamic Message Signs (DMS)

Dynamic Message Signs (DMS) are an ITS solution used on highways to provide information on traffic conditions such as congestion, travel time, weather, and work zones to road users in real-time *(6)*. It is an effective way to alleviate the problem of freeway congestion and significant delays by informing drivers of downstream traffic conditions which can occur due to traffic incidents or weather conditions. In recent years, DMS have been widely used throughout the nation. According the report in 2005 ITE journal, more than 4,500 DMS have been installed and operated by nearly 100 agencies *(7)*. On Maryland's Department of Transportation website, one map of information devices distributed in Maryland freeways shows that although a large amount of devices are installed, most of them are offline or online without any information *(8)*. Based on the travel time reliability of I-495 corridor, DMS are suggested to be used in the freeway to release the congestion. However, to demonstrate the importance of appropriate use of DMS, a through literature review was conducted. There are many researchers that have evaluated the DMS through mathematical methods and cases study, supporting that it is really a helpful way to solve the congestion problem.

One study *(6)* evaluated the DMS of the MRR1 network in Kuala Lumpur by comparing the travel time and the proportion of roadway length covered by vehicles at the peak hours. The result shows that the network with DMS is widely benefited *(6)*.

One study *(9)* of evaluation of DMS was based on the simulation and modeling. The model used the method of successive average algorithm to achieve stochastic user equilibrium at each sampling interval. A numerical example of using DMS in Beijing was also used to illustrate the effects of the DMS. The result showed that with the DMS, congestion can be alleviated. Meanwhile, the user travel time and link service level can be improved at the network level *(10)*.

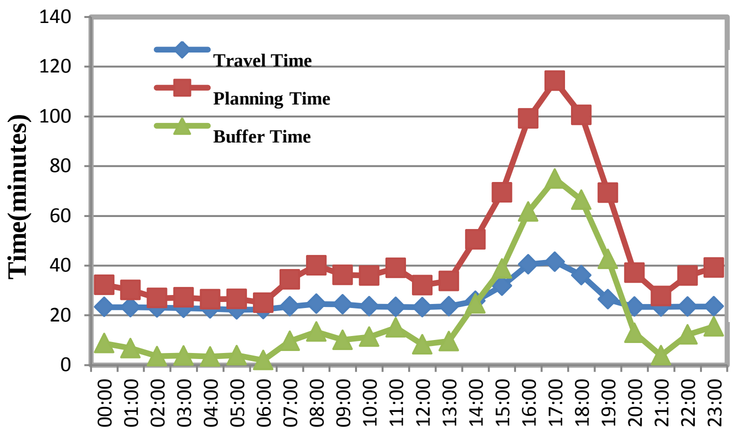
Another study *(10)* investigated the guidance benefit of travel time displayed by DMS. The investigation adopted macroscopic dynamic traffic network modeling method to combine travel time calculation model and route guidance model with macroscopic traffic simulation model. The case study showed a result that high efficiency of travel time displays by DMS can significantly release congestion caused by incident. *(10)*.

Analysis on the I-495 Corridor (From Intersection I-66 to I-95 Segment)

Travel Time reliability

The north I-495 corridor from the intersection of I-95 to the I-66 intersection is a part of the corridor around Washington, D.C., covering two states: Maryland and Virginia. It is in the most significant congestion area in the United States. Travel time reliability analysis is an effective way to evaluate the traffic status and condition of congestion. Furthermore, it can be used to prioritize improvements as well.

Figure 2 shows the travel time of the corridor between the intersection of I-95 and the intersection of I-66 on I-495 in May 2012. As shown in Figure 2 the travel time across the segment varies considerably throughout the day. Its variability increases during the afternoon peak period (about 15:00 to 19:00), which was highest at about 43 minutes. The mean travel time was 25.93 minutes, the standard deviation was 5.59 minutes, and the coefficient of variation was 25.9%. Figure 2 also shows the buffer time for every hour. During the peak time, it exceeded travel time to the highest point by nearly 80 minutes. But the average buffer time is 19.32 minutes. Figure 2 also indicates the planning time which was 45.39 minutes on average, but it climbed to nearly 120 minutes at the 5:00pm peak . For a traveler who wants to be at least 95% of the time on time, 45.39 minutes should be reserved to travel through this corridor except during the peak hour in the afternoon.



Mean travel time=25.93

Standard Deviation=5.59

Coefficient of Variation=25.9%

Figure 2: RITIS every day of the week Travel time, Planning Time, Buffer time in May 2012.

Figure 3 and Figure 4 show the mean travel time of a day in clockwise and counterclockwise direction, respectively. The travel time of different months can be clearly compared in the figures. As can be seen in the Figure 3 there was just one sharp peak of travel time of a day on the clockwise segment, which was between 14:00 to 19:00. But the counterclockwise segment had 2 peaks: one was in the morning around 8:00 am; the other was also at 14:00-19:00. Even though there were 2 peaks on the counterclockwise segment, the peak travel time was just 34 minutes, which was the half amount of that on clockwise. These two figures also illustrate the most important travel situation to consider; there is a significant traffic time increase at PM peak in June. This means that these two direction segments were both in the condition of heavier traffic which could result in congestions during the peak hour. The increase could be caused by bad weather, the increasing number of the travelers, or the deteriorating road surface condition.

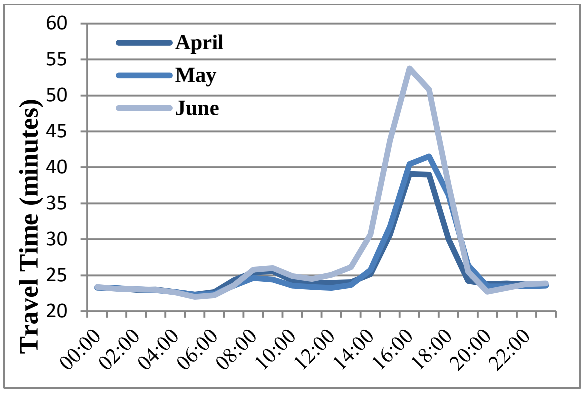


Figure 3: Travel time comparisons, I-495 from I-66 to I-95 segment Clockwise, April, May, June, 2012.

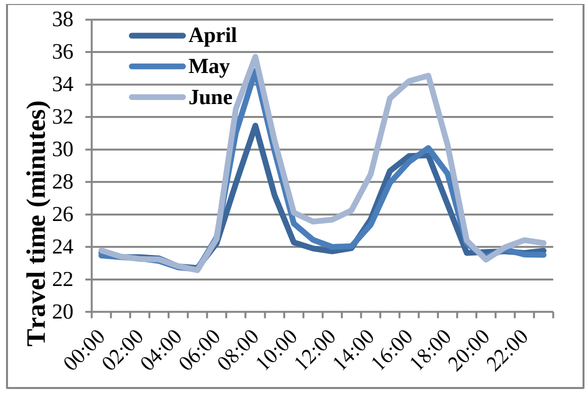


Figure 4: Travel time comparisons, I-495 from I-66 to I-95 segment Counterclockwise, April, May, June, 2012.

Table 1 shows how the travel time index and buffer index of two direction segments changed from the previous month. It is a reference from the Federal Highway Administration (FHWA). As it shows, every change was in an increasing trend, especially the change of buffer index of the counterclockwise direction in June, which is much higher than others. In Table 1, the darker the arrow is, the more significant of an increase it is, such as the clockwise buffer index grew up rapidly in May and June and counterclockwise grew in June. This result has the same trend with the travel time comparison which showed in the Figure 3 and 4.

Table 1: I-495 from Intersection I-66 to Intersection I-95 segment Travel Time Index and Buffer Index change conditions From April to June.

Travel Time Index				
	Clockwise	Change	Counterclockwise	Change
April	1.1113	-	1.0758	-
May	1.1254	0.0142 ↑	1.0979	0.0221 ↑
June	1.2129	0.0875 ↑	1.1513	0.0533 ↑
Buffer Index				
April	0.5400	-	0.4746	-
May	0.6538	0.1138 ↑	0.4750	0.0004 ↑
June	0.8358	0.1821 ↑	0.8017	0.3267 ↑

Changes from April to June

Figure 5 shows the clockwise plot's average travel speed. The x-axis represents the time of day. The y-axis indicates the exits along the I-495 corridor. The area showed in green is in high speeds and the area in yellow and red represents low speeds. The figure shows that, in April, there was just a small area covered with light red color which means the road was generally in a high speed condition except the region from Exit 34 – Exit 35. However, the lower speed area in April expanded to Exit 33 – Exit 35 in May. In June, not only the region and the peak time expanded, but also the degree of congestion increased. Especially on the area of Exit 35, the condition was very bad with the average speed is down to 19 mph.

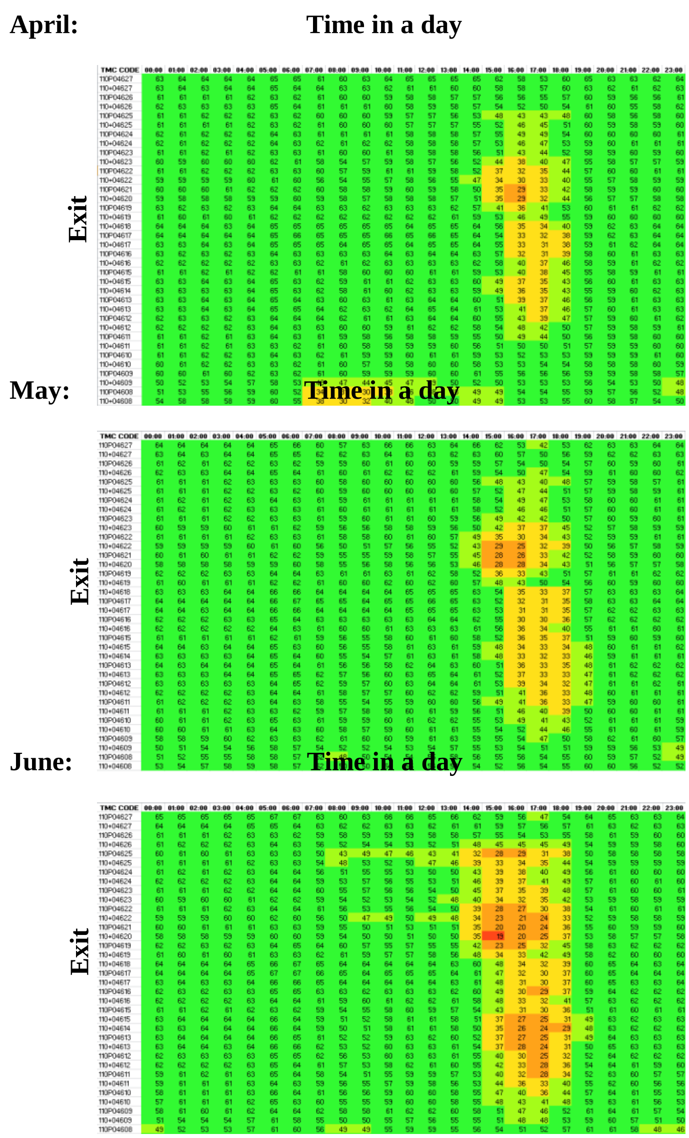


Figure 5: Clockwise Plots Average Travel Speed

In addition, the day of the week buffer index during the April to June was analyzed. In Figure 6, it is obvious that, in the clockwise direction, the buffer index peaked at over 1.2 at Friday. Tuesday and Thursday ranked second at about 0.85. The buffer index of Wednesday was the highest in the counterclockwise. The first 3 highest buffer indices did not vary as significantly as that in the clockwise direction. Generally, the buffer index of the clockwise direction was higher than that of counterclockwise.

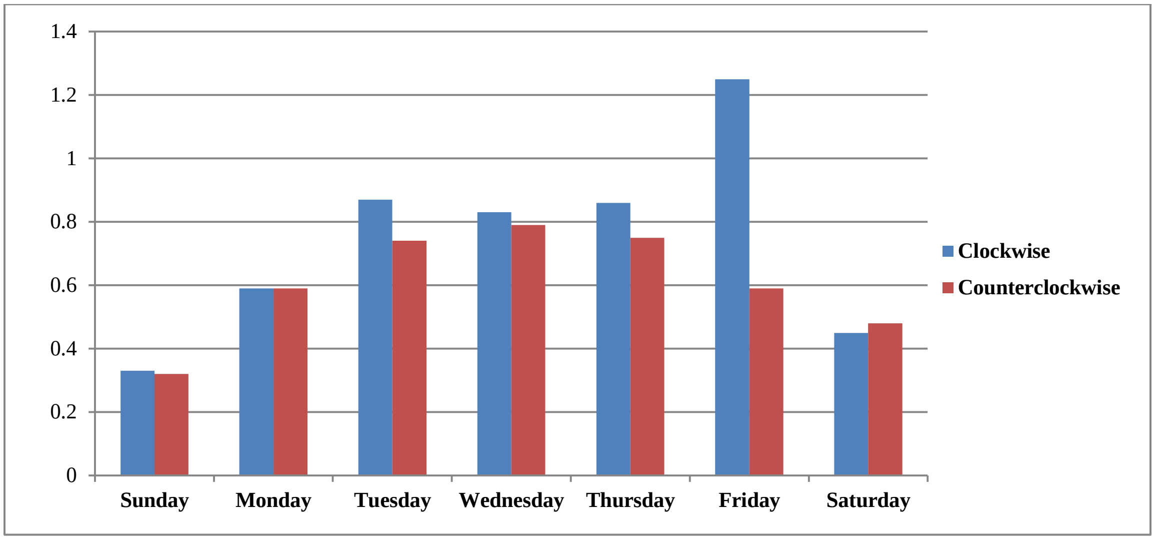


Figure 6: Day of Week Buffer Index of Clockwise and Counterclockwise.

Based on these 4 methods of analysis, it can be concluded that the corridor in June was in the worst condition which means more travel time. The congestion is trending to an increasing problem. Among the 7 days of a week, the congestion levels in different directions are not the same. In the clockwise direction, more attention needs to be paid to Friday's traffic; however, measures should be taken to deal with the traffic congestion of all of the workdays for the counterclockwise direction.

Solutions

Dynamic Message Signs (DMS)

With the increasing concern on traffic congestion in most metropolitan cities and corridors, ITS solutions are the most effective ways to manage traffic. Dynamic message signs are included in ITS solutions which are the devices to provide traffic information to travelers. It can release the problem of congestions and improve the safety of the road. Nowadays, a lot of DMS have been installed and operated on many roads, and get a considerable improvement on the traffic situation. According the travel time reliability analysis on I-495, the freeway congestion has an increasing trend. Additional DMS are recommended to be installed although some information devices have already been installed on the I-495 corridor, yet most of them are offline or without information. (Showed in the MDOT website)

DMS function by first connecting to traffic sensors or video detections which collect the data. This kind of raw data has been collected by the Regional Integrated Transportation Information System (RITIS). DMS can take full advantage of it to provide more information to the travelers. Then, after processing and analyzing by the processing center, data with the various traffic guidance messages can be dispatched and sent to the corresponding DMS devices. The co-operational system of the distributed DMS can ensure them to be coordinated well in one rule operation *(11)*.

DMS location analysis

The location of the DMS and distance between them are decided by many factors, such as land-use layout, road network layout, traffic volumes, and road congestion type. Distance from the nearest exit, accident rate and travel speed, type of congestion (V/C), and static signs all should be taken into considering the location of the DMS *(12)*.

To research on the congestion of different parts of the I-495, the I-495 corridor (between intersection of I-66 and I-95) is divided to 10 segments by interval of 2 exits. The average monthly (April to June) buffer indices of these 10 segments were different between the clockwise and counterclockwise direction. As shown in the Figure 7, the buffer index of every segment was in the rising trend. Especially at Exit 11-13 and Exit 36-34 in Maryland, the buffer index went up rapidly and reached the peak among all the segments during the three months. It is also obvious that from Exit 9 to Exit 11, the buffer time always remained at a comparably high level and also increased in June. This means that the segment from Exit 9-11 was historically congested. However, in the counterclockwise direction, the highest buffer index was on the segment from Exit 13 to the American Legion Bridge. The buffer index in June was nearly doubled to that in April. Most parts of the segment’s buffer index increased rapidly. Therefore, the DMS are necessary to be installed on the location prior to these parts so that the traffic information could be provided to drivers in advance and ensure drivers have time to determine whether to change routes. In this case, not only it could save the time of travelers but also release the congestion on these segments.

Despite the factor of congestion, incidents should be also taken into consideration when determining the location of DMS. Because DMS is a device that provides valuable information to drivers, and it needs drivers to divert attention from driving to what are displaying on DMS. If there is a high incident frequency spot, it is not suitable for a DMS. On the other hand, the DMS should be at a proper distance prior to that spot to warn the traveler in advance, so that drivers can pay more attention. See Figure 9, incidents happened in the April, May and June were mostly at the Exit 31 and 33 in Maryland. Therefore, it is not recommended to install DMS near these two exits. Moreover, the information about these high incident frequency exits could be displayed on DMS in advance.

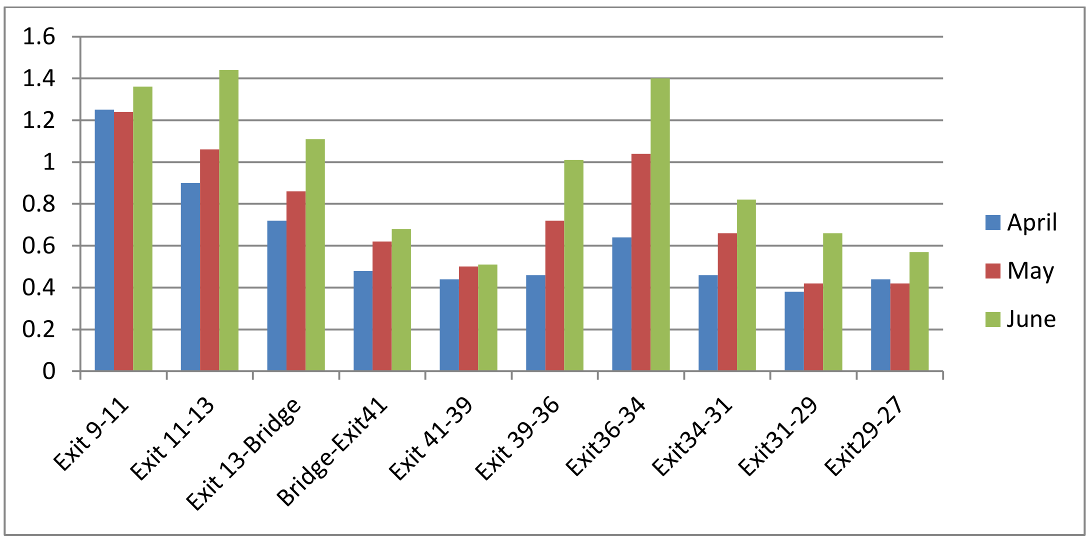


Figure 7: Buffer Index of Clockwise in April, May and June.

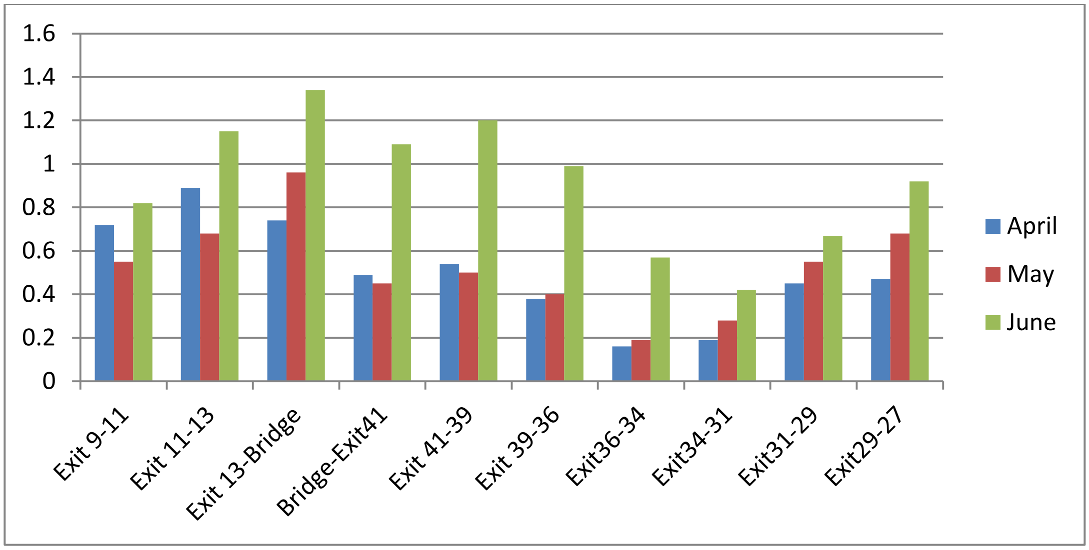


Figure 8: Buffer Index of Counterclockwise in April, May and June.

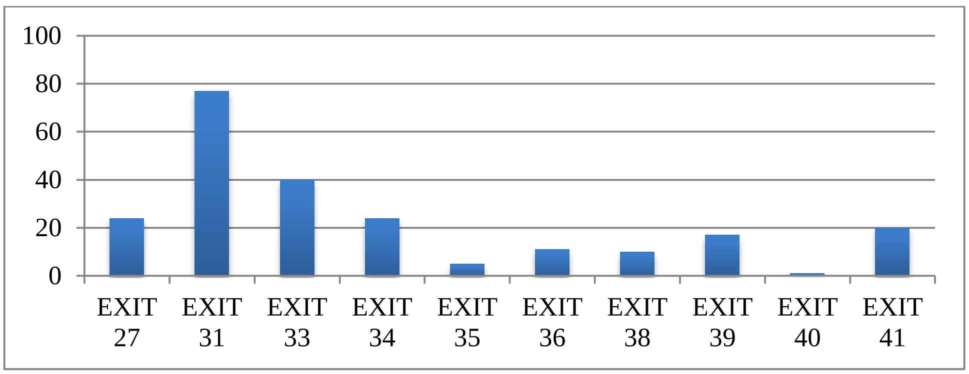


Figure 9: Incidents on Exits

Conclusion

This study first analyzes the travel time reliability of the I-495. The result shows that it is has congestion, especially during the peak hour which is about 15:00 to 19:00. The planning time at the peak point of a day was an average of 120 minutes. Comparing the travel time over three months, there was a significant increase in travel time in June in both the clockwise or counterclockwise direction. To prove this increase indeed exists, the study lists the table of travel time index changes during these three months. Another figure of the average speed with different colors in different areas was also shown with time in the abscissa and the exit location in the ordinate. The results show that congestion is definitely growing, and the congestion areas are expanding. Among the 7 days of week, the busiest day in clockwise was Friday, but Wednesday in counterclockwise.

Based on these analyses, the ITS solution of installing DMS is recommended. It is an effective way of alleviating congestion. According to the evaluation of DMS from many researchers, it really can decrease congestion and ensure the efficiency of the traffic. Many examples of other freeways or metropolitan areas successfully used DMS to improve the transportation situation, and support that DMS is a valuable and good choice to solve the congestion in I-495. This paper also analyzed the most congested segments, which is one of the factors determining the location of DMS. They should be installed prior to the congested segment as well as avoid the high frequency incidents spot.

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