2013 Student Competition

ITS HEARTLAND CHAPTER

DREAM? OR DREAM COME TRUE?

I-495 CONGESTION & ITS SOLUTION

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Table of Contents

Abstract 2

1. Introduction 3
2. Data Analysis 3
   - 2.1. Bottleneck 3
   - 2.2. Location of events 4
   - 2.3. Travel Time and reliability 6
   - 2.4.Incidents/time duration and relation to bottleneck 7
3. Results 8
   - 3.1.Recurring or non-recurring congestion? 8
   - 3.2.How reliable is this section of roadway? 8
   - 3.3.To what degree to do incidents impact reliability? 9
   - 3.4.To what extent is congestion impacting the freeway capacity? 9
   - 3.5.Adjusted bottleneck duration index 9
4. ITS Solution & Conclusion 9
5. References 10

Abstract

In mega cities, surrounding highway plays key role in transportation system. However constant congestion from peak and non-peak hours, and non-recurrence events reduce flow and speed of highway system. In this paper, using RITIS data, congestion in northwest of I-495 will be analyzed and answered asked by transportation officers. It is found that congestion is occurred by excess demand of flow and daily recurring peak hours. Bottleneck is 40% source and incidents are 25% source of congestion. These two sources were mainly focused and analyzed. Incidents time had impacts 33% in MD in terms of duration. In VA, traffic incident management has to be reviewed, because number of incidents and impact rate on bottle neck is severe.

1. Introduction

Congestion in highway system is major issue that happens every day. The Capital Beltway, in Maryland, Virginia and Washington, D.C area, also deals with heavy congestion and ranked 7th the worst physical bottlenecks in the United States[(1)] with 19,429 annual hours of delay. VDOT and MDOT implemented projects to increase capacity of I-495, such as expansion of lanes, localized bottleneck reduction (LBR) [(2)], express lane built.

According to Federal Highway Administration (FHWA), major source (40%) of congestion is bottleneck. Second source is traffic incidents with 25% [(1)]. Finding solution of bottleneck problem and its relation with incidents can significantly reduce major portion of congestion. It showed that the worst bottlenecks are ‘freeway to freeway’ interchange which requires major road improvements. However, office of operation (OPA) at FHWA described many bottlenecks are ‘bottleneck systems’ where traffic flows are influenced by several smaller bottlenecks. FHWA recently started to develop programs to reduce recurring traffic bottlenecks with low-cost operational improvements.

In the paper, segment of I-495 has 15 interchange areas ‘bottleneck systems’ and 3 freeway to freeway. Data analysis will be focused on these interchange areas’ bottleneck and related

incidents. Along with FHWA's projection of low-cost and requirement of this competition, number of suggestion will be discussed.

2. Data Analysis

The Regional Integrated Transportation Information System (RITIS) at University of Maryland provided data. Study area for data analysis was limited from exit (I-66) to exit 27(I-95) and second quarter of 2012 to meet requirement of competition.

In the following data analysis, Maryland (MD) and Virginia (VA) were separated, because current formation highway systems are not equally identical. VA side has two lanes of high occupancy toll (HOT) for each direction with toll system up to exit 45. MD side does not have toll and express lane system yet. Also incidents rate for two states were significantly different. VA side has more events (760) with shorter distance (approximately 4 miles and 6 exits), while MD side has fewer events (653) with longer distance (approximately 10 miles, 10 exits and 1 junction). In MD, most events occurred near exits area, while VA side events less congregated and more dispersed. These differences were accounted in data analysis.

Road maintenance, 10% source for congestion [(1)] and minor events were not analyzed in this paper. It was mainly focused on collision, disabled and incidents related types of events.

2.1.Bottlenecks

To discover recurring congestion, bottleneck data was analyzed. Overall average duration of both states had little over an hour; 1 h 6 m in MD and 1 h 2 m in VA. Average max length (miles) in MD, 3.1 miles, was longer than 2.4 miles of VA side. For number of occurrence, VA has 86.8 times of occurrence while MD has 45.7 times of occurrence. Impact factor which is multiply of

average duration, average max length and occurrence for both states are similar, 18,831.4 in MD and 19,689.6 in VA. VA situation was worse than MD.

For average max length of bottleneck, except only one exit in MD with 0.36 miles, all the other exits in both directions has greater than 1 mile or very close to 1 mile. This explains the Northwest corridor of I-495 does not function as a highway, but turn to be a huge parking lot in peak time of day, as OPA noted, because length is longer than next exit distance and they were connected.

Table 1. Top three bottleneck spots and overall of each states

states	Exit	Avg duration	Avg max length (mi)	Occurrences	Impact factor
MD	28 (CW)	2 h 32 m	6.98	133	141,090
	31(CCW)	1 h 46 m	3.59	128	48,758
	Spur (CW)	2 h 17 m	5.55	134	101,910
	overall	**1 h 6 m**	**3.1**	**45.7**	**18,831.4**
VA	12(CCW)	1 h 39 m	4.83	134	64,028
	10(CCW)	1 h 24 m	3.2	214	57,537
	9(CCW)	1 h 40 m	4	102	40,840
	overall	**1 h 2 m**	**2.4**	**86.8**	**19,689.60**

Thirteen exits were over 70 times of occurrence in 14 weeks, 70 week days of 2nd quarter of 2012. These exits experience at least 1 time of each weekdays.

An interesting issue is the direction of bottleneck. In MD, impart factor of clock wise (29,328.8) is almost three times of counter clock wise (10,756.5), based on different level of occurrence. In VA, appearance of symptom is opposite of MD that impact factor of counter clock wise (29,724.2) was worse than clock wise (9,655).

Table 2. Bottleneck duration, occurrence and impact factor for each direction and states

states	direction	Avg duration	Avg max length (mi)	Occurrences	Impact factor
MD	CW	1:10:36	3.0	58.4	**29,328.8**
	CCW	1:03:46	3.1	36.0	10,756.5
VA	CW	0:52:50	1.8	70.3	9,655.0
	CCW	1:12:50	3.0	103.2	**29,724.2**

2.2.Location of events – intersection area

Most events were located in intersection area. In VA side, 65.4% events (506/774) were located in intersection area. 92.4% of Maryland events (659/713) are located in intersection area. Each location was individually counted as in intersection area, if latitude and longtitude location is within merge/diverge area of each interchange. It was oppostie of expectation that more events were concentrated in Maryland with wider interval of exists.

Exit 31 (17.8%) and 28 (16.1%), in Maryland, had double amount of events compared to other exits. In Virginia, exits 45 (29.6%) and 46 (21.5%) had more events than others. And these four exits were only exits with over 100 events in total of 2nd quarter. It was preassumed that major interchange area, where two interstate highway interchange, could be major events area. However three exits were not the major interchange spots.

Table 3. Types of event happened in each exits, Maryland.

MD	41	39	spur	36	35	33	**31**	30	29	**28**	27	Total	%
Collision	14	12	10	2	17	18	**31**	13	18	**29**	13	177	93.7
Disabled	33	25	13	13	37	37	**68**	31	28	**57**	23	374	91.0
Incident	2	1	1	0	0	1	**2**	4	4	**4**	2	21	100.0
Injury	1	3	0	1	0	3	**4**	2	6	**3**	2	25	92.6
Obstruction	8	7	1	5	1	6	**12**	3	4	**13**	2	62	95.4
Total	58	48	25	21	55	65	**117**	53	60	**106**	42	659	**92.4**
%	8.8	7.3	3.8	3.2	8.3	9.9	**17.8**	8.0	9.1	**16.1**	6.4	100.0	

Table 4. Types of event happened in each exits, Virginia

VA	43	44	**45**	**46**	47	49	Total	%
Collision	13	11	**37**	**26**	15	21	123	73.7
Congestion	19	0	**23**	**15**	1	3	61	57.0
Disabled	15	33	**85**	**60**	57	42	292	63.5
Incident	7	0	**5**	**8**	6	4	30	75.0
Total	54	44	**150**	**109**	79	70	506	**65.4**
%	10.7	8.7	**29.6**	**21.5**	15.6	13.8	100.0	

2.3.Travel time and Reliability

In this specific corridor (from exit 49 to exit 27), peak hours separated based on direction – clockwise and counterclockwise. For clockwise, peak hours are from 2 pm to 7 pm with planned time over 60 minutes. For counterclockwise, peak hours are from 7 am to 9am and from 2 pm to 7 pm. Defining peak hours for each direction is important to find out impact ratio of non-recurring congestion from overall congestion. In this paper, peak hours are set 7am – 10am (AM peak) and 2pm – 7pm (PM peak) where plan time index is over two.

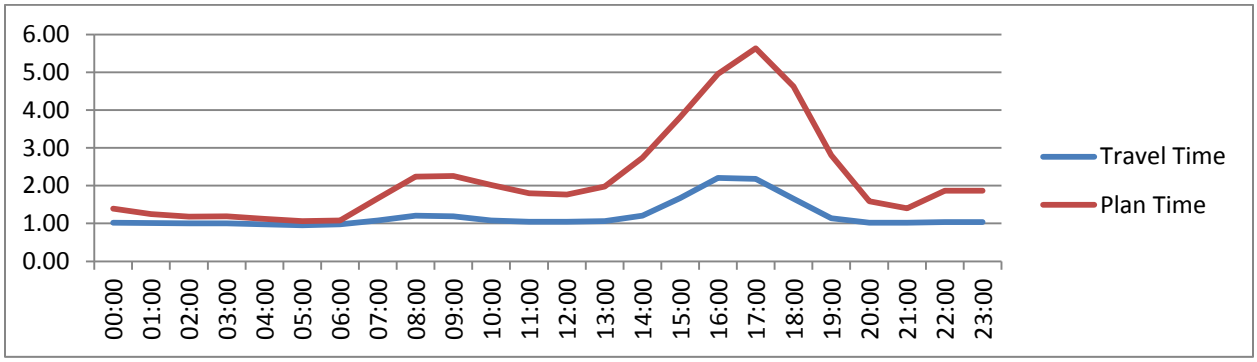

Figure 1. Hourly of weekdays, average of plan time, buffer time and travel time of clockwise, 2nd quarter

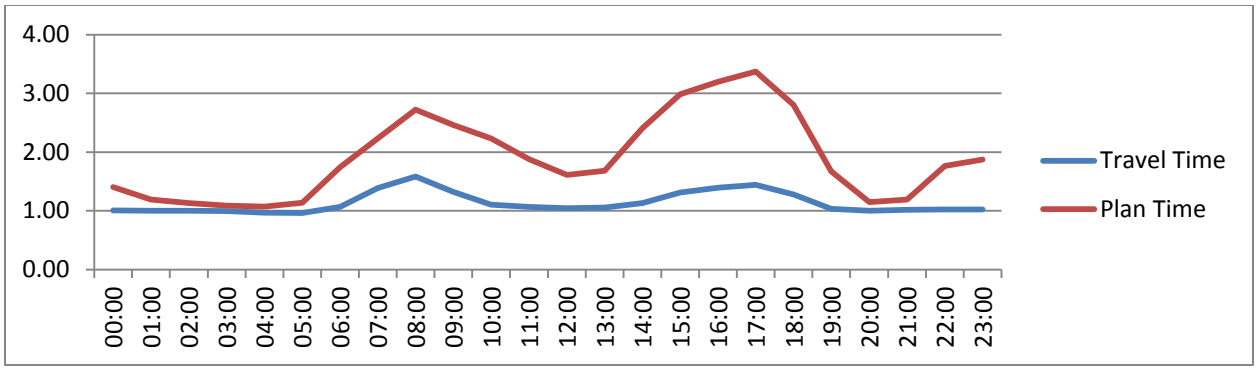

Figure 2. Hourly of weekdays, average of plan time, buffer time and travel time of counter clockwise, 2nd quarter

Figure 1 and 2 shows that in the AM peak time, counter clockwise (CCW) had slightly higher plan time index (2.72) than clockwise direction (CW) with 2.26. In the PM peak time, returning movement increased 49% from CW to CCW and 107% increased from CCW to CW. More commuters move from VA side to MD side, because AM peak was higher in counter clockwise and PM peak was higher in clockwise.

2.4. Incidents/time duration and relation to bottleneck

This section is analyzed to discover how much incidents has impacts on bottleneck occurrence. Incidents rate in peak hour's event is 56.3% in Maryland. In Virginia, it was less than half, 47.5% occurred during peak hours.

Table 5. Types of events during peak hours and percentage

Type	MD peak hours				VA peak hours				SUM			
	AM	PM	Total	%	AM	PM	Total	%	AM	PM	Total	%
Collision	47	58	193	54.4%	40	43	172	48.3%	87	101	365	51.5%
Obstruction	11	18	65	44.6%	3	81	107	78.5%	14	99	172	65.7%
Disabled	79	168	413	59.8%	71	130	471	42.7%	150	298	884	50.7%
Incident	14	10	48	50.0%	4	4	41	19.5%	18	14	89	36.0%
Total	151	254	719	**56.3%**	118	258	791	**47.5%**	269	512	1510	**51.7%**

Table 5 shows relation between types of events and peak hours of each state. Overall 51.7% of events happened in peak hours. Almost double amount of events happened in PM peak than AM peak correlated with plan time index that PM was higher. It was expected that higher speed condition causes more accidents. However, considering with combination of higher planning time index, events occurrence was related with more level of flow and planning time index than speed level.

Table 6 is set to find out peak hours events are less severe than overall events severity. Overall duration of event between peak hours and non-peak hours were not significantly different. It was assumed that duration of peak hours expected shorter than total average duration. Because it was assumed slower speed causes less severity event than higher speed. It varies with each type of events. In case of incidents, during peak hours, it took less than half of overall incidents events. Duration of obstruction and congestion caused by incidents, by agency specific type, were longer than other types of events. Especially in Virginia, it was over 2 hours.

Severity of VA side events were higher than MD side in both total time and average time of overall and peak hours, along with higher number of events.

Table 6. Types of events duration of peak hours

Type	MD				VA				SUM			
	Total	Avg	Peak Total	Peak Avg	Total	Avg	Peak Total	Peak Avg	Total	Avg	Peak Total	Peak Avg
Collision	76:22	0:23	48:34	0:27	223:17	1:17	81:33	0:58	299:39	0:50	130:07	0:43
Obstruction	35:38	0:32	13:41	0:28	263:18	2:27	211:12	2:30	298:56	1:30	224:53	1:29
Disabled	121:14	0:17	75:20	0:18	217:00	0:27	112:14	0:33	338:14	0:22	187:34	0:25
Incident	16:02	0:20	8:31	0:21	18:07	1:48	3:33	0:26	34:09	1:04	12:04	0:23
Total	249:16	0:23	146:06	0:23	721:42	1:30	408:32	1:07	970:58	0:57	554:38	0:45

3. Result

3.1. Recurring or non-recurring congestion?

It was combination of both recurring and non-recurring. But major portion came from recurring congestion. Hourly congestion, shown with travel and planning time index with weekdays, had pattern that is similar through 2nd quarter as well as other period. It was because most vehicles used for commuting for jobs.

3.2.How reliable is this section of roadway?

To check reliability buffer time can be used. AM peak hours for clockwise was 13.2 min – 25 min and 22.3 min – 31.7 min for counter clockwise. Buffer times for PM peak hours are much higher that 22.5 min – 91.1 min for clockwise and 16.8 min – 46.1 min for counter clockwise. AM peak hours can be considered to be reliable. PM peak hours are hard to be in reliable part. In terms of events - non-recurring congestion - duration minutes was moderate in Maryland side, but in Virginia side was not reliable.

3.3.To what degree to do incidents impact reliability?

Average duration of incidents or non-recurring events was in a range of buffer time. But for PM peak hours, buffer time was not in a range of duration. It was even more than 1 hour from 3pm – 6pm.

3.4.To what extent is congestion impacting the freeway capacity?

Combined congestion, both recurring and non-recurring, causes more than one hour of duration for each exits in both states. It significantly drops flow of the freeway capacity.

3.5.Adjusted bottleneck duration index

Adjusted bottleneck duration can be defined as;

Adjusted bottleneck duration

= duration time – events duration (average duration of specific type incidents)

, which can provide pure duration of congestion without any non-recurrence events. It can provide idea to daily/weekly/seasonal bottleneck information. In MD, average of 23 min duration is 33% of bottleneck time, while in VA one hour and 7 min, which was greater than to average bottleneck time.

4. ITS solutions & Conclusion

After analyzing data of recurring congestions and unexpected congestions and reviewing current ITS systems, two ITS methods are suggested. Data analysis shows that every interchanges' are congested during peak hours.

To reduce short-distance travelers, the number of cars entering in the system should be controlled to prioritize long distance travelers. To provide more access for long distance travelers, short distance travelers should be limited, especially during peak hours. Installing ramp meters in critical exits can control number of cars that enters in the I-495 system[(4)(5)] .

Based on bottleneck data with impact factor, more congested exits should be considered to install ramp meter system. The highest impact factor exit is, in Maryland, Exit 28 (MD-650) with 141,090. Next one is Exit 31 with 48,758 impact factor. Exit 33 and Exit 34 cases impact factor (28,768 and 19,650) are also higher side. The part we need to concern is number of occurrence is relatively smaller compared to other exits. And average max length (miles) and average duration are longer. So once bottleneck starts, these two exits have more impact than others. So MDOT should plan to control bottleneck by putting ramp meters in these Exits as well.

For Virginia state, Exit 12 and 10 (64,028 and 57,537) have higher impact factor. Exit 14 (GW Memorial Pkwy) has small number occurrence (19) compared to others (86 – 134). Duration (1h 14m) and max length (3.41 miles) are relatively higher side.

Most Exits have more 2 miles of average max length and average of 3.76 miles. They are connected as a long line of cars in peak hours, considering average distance between exits is less

than 1 mile. With 84 times of occurrences, considering week days only, on average, bottleneck happens more than 3 times a day.

Another possible suggestion to both states DOT to have ITS method is to install Direct Message System on I495. In Maryland side on I-495, there was three DMS[(3)]. In Virginia side on I-495, it has only one active DMS. Adjunct interstate highways, I-95, I-270 and I-66 have 1 DMS per mile close to DC area. DMS can be set up starting with high congestion areas – high impact factor Exit areas. There are three messages to suggest; a. long distance– use left lanes; b. Be cautious - high accident areas; c. congested next 1hr – use local.

In VA side, it is highly recommended to review traffic incident management system. Because of number of incidents per miles and severity of events were absolutely higher than MD. Without spending high cost for major construction system, this low-cost reviewing can significantly reduce traffic incidents.

For MD side, 23 min of event time duration affected on bottleneck time of 1hr and 6 min – 33 %. For VA side 1hr 7 min of event time duration affected on bottle time of 1hr and 2 min. Again, in VA side, events had heavy effect on bottleneck.

5. References

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(4) Hajbabaie. Ali, Benekohal. Rahim, Does traffic metering improve network performance efficiency? IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, p 1114-1119, 2011, 2011 14th International IEEE Conference on Intelligent Transportation Systems, ITSC 2011

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