PROJECT REPORT

Measuring Travel Time Reliability of Transportation Systems

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ABSTRACT

When traveling people want to be on time and avoid any traveling delays. We worked to determine travel time reliability along the I-71 corridor. This study will provide a buffer time index that will determine specific travel times along different segments of I-71. We analyzed the stability of the quality of service of this particular transportation system is supposed to provide to its users was analyzed. An advanced GPS data collection method was used to provide travel times along specific segments of I-71 along with volume data from ARTIMIS surveillance video. We expect to find travel time reliability and average delay times using the 85th percentile travel speed, and the 95th percentile of travel times. Furthermore, we determined the critical segments of the trips and calculated how this affects the travel time, buffer time, and the planning time. Finally, to predict within 95% probability the travel time along I-71. As an example, the buffer time of 12 min and 17 sec is needed to achieve a 95% on time arrival rate on the southbound I-71 section.

KEY WORDS

Travel Time, Freeway Reliability, Level of Service, Buffer Index, Planning Time Index, Delay

1. INTRODUCTION

Transportation Engineers work in a field where they must collect and analyze data and compare it to some of the data that has been collected by various organizations, such as ODOT and ARTIMIS in the state of Ohio. After collecting the data and analyzing it, engineers think about hypothetical situations of ways to improve traffic and keep congestion to a minimum.

Tools used:

- GPS data loggers
- Jamar traffic counters
- Manual traffic counters
- VISSIM simulation software
- Petra Pro software
- Microsoft Excel
- Highway Capacity software (HCS)

2. LITERATURE REVIEW

We began our investigation of transportation literature by looking at *Traffic Engineering: Third Edition* textbook. The authors of the textbook are professors at Polytechnic University. In the opening chapters basic terminology and concepts are introduced, as well as basic responsibilities of a traffic engineer. Chapter 9 examined speed, travel time, and delay studies, which covered our basic concepts of study. This assisted our understanding of field study techniques and data calculations, and graphical representation. Chapter 12 was particularly helpful in explaining level of service, capacity, free-flow speed and heavy vehicle factor.

Next, we examined the 2007 *Urban Mobility Report* . The authors David Schrank and Tim Lomax are research scientists and engineers who research for the Texas Transportation Institute. This resource was helpful in explaining unreliable travel times which are caused by congestion problems. It introduced planning time index, travel time index, and buffer index in a graphical format.

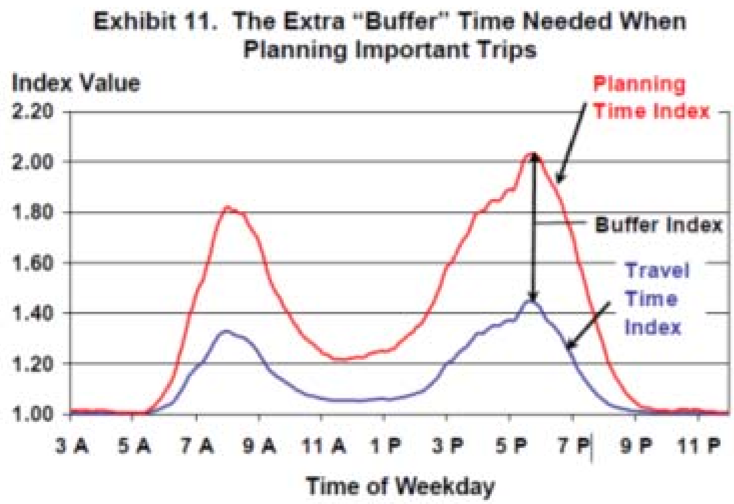


Figure 1 Illustration of travel time index/buffer time index and planning time index

Next we looked at the *Manual Of Traffic Engineering Studies*. The authors Paul Box and Joseph Oppenlander are from the Institute of Transportation Engineers in Virginia. This is a handbook of how to conduct traffic studies. This manual was useful in understanding the floating car method for measuring travel time and delays. The floating car method was the basic principle for how we should drive with the traffic flow. We also used this manual to determine the sample size for our traffic study.

We then look at *Transportation Infrastructure Engineering: A Multimodal Integration*. The authors Nicholas Garber, Lester Hoel, and Adel Sadek, are from the University of Virginia and the University of Vermont. This resourced helped clarify the capacity concept and the level of service concept. The level of service concept is something that is crucial to our analysis of the roadways in our software analysis using Highway Capacity Software (HCS). This resource defined the traffic flow parameters which include flow (q), speed (u), density (k), headway (h), and spacing (d). The three basic parameters of a traffic stream are flow, speed, and density. They are related by the equation $q=u\,k$.

We also looked at United States a brochure from the Federal Highway Administration entitled *Travel Time Reliability: Making It There On Time, All The Time*. This article defined Travel Time Reliability and explained why it is important to the field of transportation engineering. It gave formulas and examples of how to calculate TTR, calculate a Buffer Index and Planning Time Index, which are key parts to the Transportation Project.

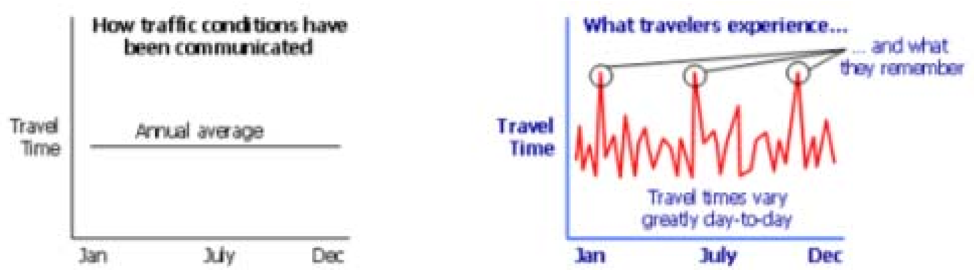


Figure 2 Comparison of cumulated and real travel time

Next, we looked at *Traffic Science*. This book examined some of the traffic flow theories. Specifically, it defined the ranges of traffic intensity. It divided the traffic intensity into three categories: light traffic, moderate traffic, and heavy traffic. This resource also defined the capacity of a roadway, bottlenecks, and gave several approaches to traffic flow theory.

3. GOALS AND OBJECTIVES

1. Find travel time reliability measures along the I-71 corridor from exit 19 to exit 1.

    Use GPS Data Loggers to acquire travel time data.

    Use Excel spreadsheet to calculate travel time reliabilities.

2. Use ARTIMIS video to determine traffic volume on I-71 and the highways level of service.

    Count cars and heavy vehicles along segments of I-71.

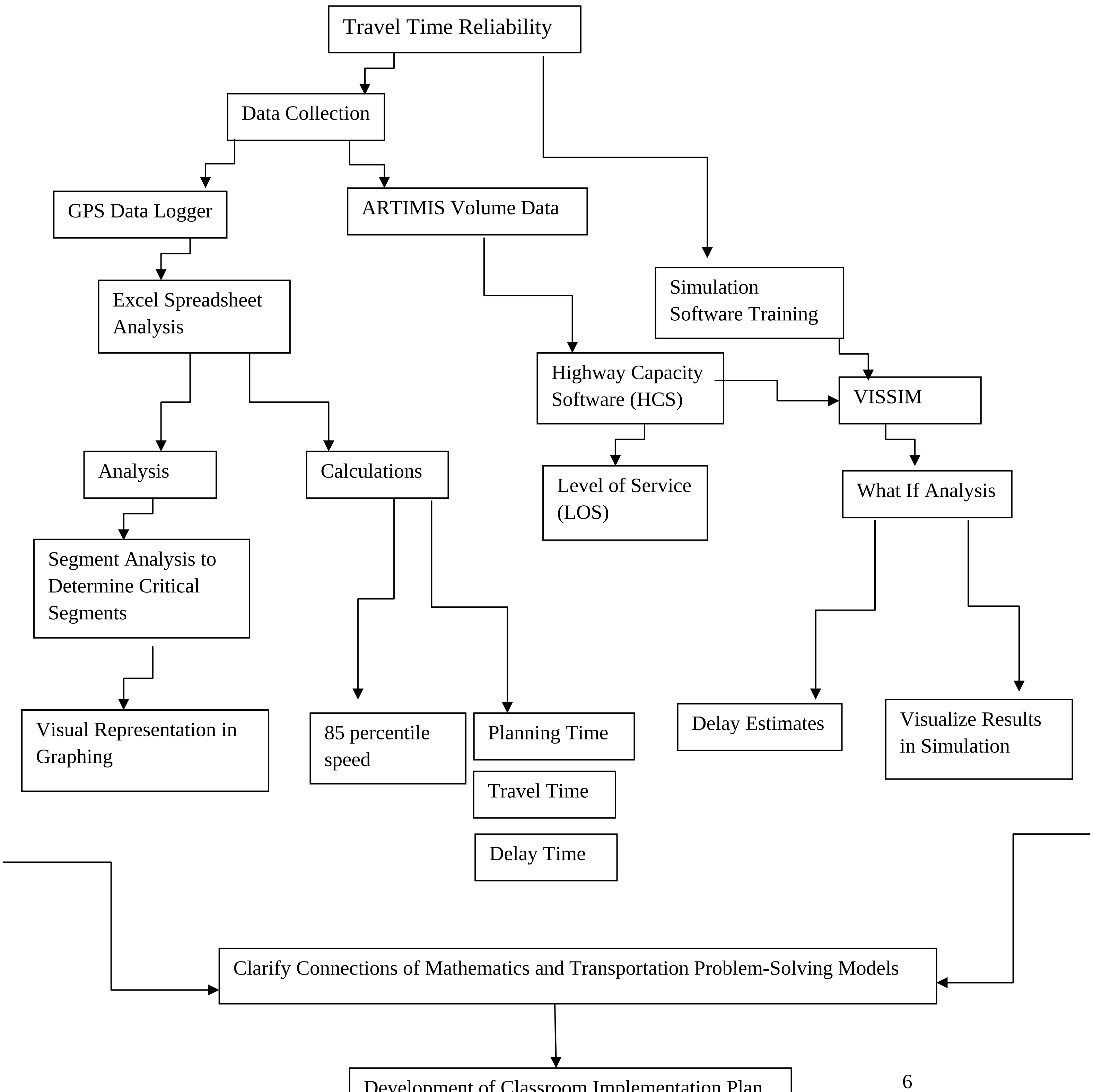
    Use HCS software to determine specific levels of service.

3. Utilize traffic simulation software to validate field data.

    Build three segments of I-71 in VISSIM software.

Validate simulation models

4. RESEARCH STUDY DETAILS



The I-71 corridor from Exit 19, Mason Montgomery Road, to Exit 1, at the Ohio River, was selected for study. Data collection began on June 30,2009 and continued through July 7, 2009. A GPS Data Logger was used to collect position, speed and altitude data in one second intervals. The position data was recorded in latitude and longitude coordinates. Researchers selected the middle lane for travel and drove consistent with traffic. Every effort was made to model the traffic flow on each trip. This is known as the floating car method of study. Collection times varied throughout the peak hours between 7am and 9am. Data collected consisted from twenty four trips southbound and fourteen trips northbound. In order to collect the data we used GPS data loggers. The GPS data logger needed to be turned on at the start of the trip and it would record the geographic coordinates, timestamps, and altitude.

Using Google Earth, I-71 was then divided into sixteen segments southbound and fourteen segments northbound. The segments were divided in a manner such that an interchange fell in the middle of each segment. This method was chosen as to model the effect each interchange had on vehicle travel time and delay. The geographic latitude and longitude coordinates of the end points of the segments were recorded for further use.

In order to view the data, the GPS needed to be plugged into a computer and uploaded to Travel Navigation software. After the data collection period was complete, the GPS data was then downloaded into the Travel Recorder software and exported as Microsoft Excel files. The data was then sorted by the day of the trip, as well as the direction of the trip. The data was segmented using the latitude and longitude coordinates of the segments. Once segmented the travel times for each segment were calculated and cataloged. Segment times were then organized as to calculate various traffic indicators outlined below.

Volume data was obtained from the ARTIMIS cameras located along the I-71 corridor. The number of cars was counted in both north and southbound sections at the Fields Ertel Road and Kenwood Road interchanges. This volume data including heavy vehicle percentages was loaded in the HCS software to determine that segment's level of service.

Lastly, we inputted the ARTIMIS volume data into HCS and VISSIM traffic simulation software in order to evaluate the level of service and to validate GPS travel times.

Table 1 Volume counts at Fields Ertel exit from ARTIMIS video

Volume Data for Fields Ertel Exit (5 minute intervals)				
	north		south	
	cars	trucks	cars	trucks
7:00	103	23	406	28
	150	19	266	45

7:30	137	26	432	26
8:00	151	25	323	26
Average	135.25	23.25	356.75	31.25
Avg per hour	1623	279	4281	375
Percent Trucks		0.171904		0.087596

Table 2 Volume counts at Kenwood exit from ARTIMIS video

	Kenwood Road (6 minute intervals)			
	north		**south**	
	cars	**trucks**	**cars**	**trucks**
	447	34	347	28
	509	40	454	52
Avg	478	37	400.5	40
Avg per hour	4780	370	4005	400
Percent trucks		0.077406		0.099875

By using a traffic counter, we were able to watch ARTIMIS recordings of Fields Ertel Road and Kenwood Road. We counted the number of cars in five minute intervals for a series of videos recorded at different times on the same day. We then found the average number of cars to pass in various minute intervals, and then converted them into hour intervals. We repeated this process for trucks

5. ANALYSIS: RESEARCH RESULTS

The analysis of the data began when the segments were profiled to determine which segments had the highest variation from the median travel time. The graphs showed the frequency of trips and the travel time in seconds. The x axis of the graph was the median travel time. Section 4 at the Ronald Regan interchange and Section 7 at the Norwood Lateral interchange were determined to have the most variation in travel time on the south bound section of I71. On the northbound section of I71, Section 9 the Red Bank Rd interchange showed a high variation in travel time. All section profiles can be found in Appendix II.

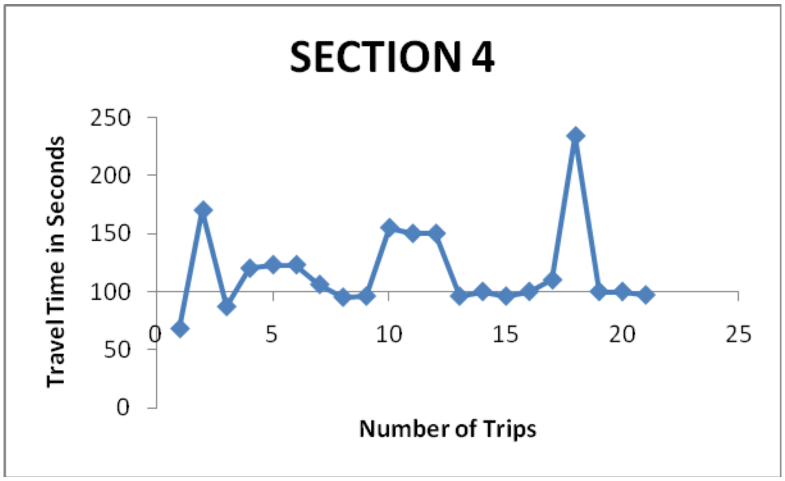


Figure 3 Travel Time distribution for Seg. 4 SB

This graph shows critical segment number 4 going southbound. The travel time seemed to be more unreliable than the other graphs and that is evident by looking at the peaks on the graph and noticing the varying distances of the peaks from the median line.

Using Excel the following Travel Time Reliability Measures were found:

- **Buffer Time –** The time that is added to the Average Travel Time to ensure 95% on Time arrival. This time is calculated by: 95th percentile time - Average travel time
- **Buffer Time Index –** Buffer Time / Average travel time
- **Travel Time Index –** Average travel time / Free Flow time
- **Planning Index –** 95th percentile time / Free Flow time

The study results show that a Buffer Time of 12 minutes 17 seconds needs to be added to the southbound section of travel to ensure 95% on time arrival. Therefore, the Planning time for the south bound section of I71 is: Average time + Buffer time = 34 minutes

The northbound Buffer Time is 2 minutes 21 seconds so using the above method the northbound Planning is 21 min 26 sec.

In Appendix II a spreadsheet is provided that lists the above measures for each segment.

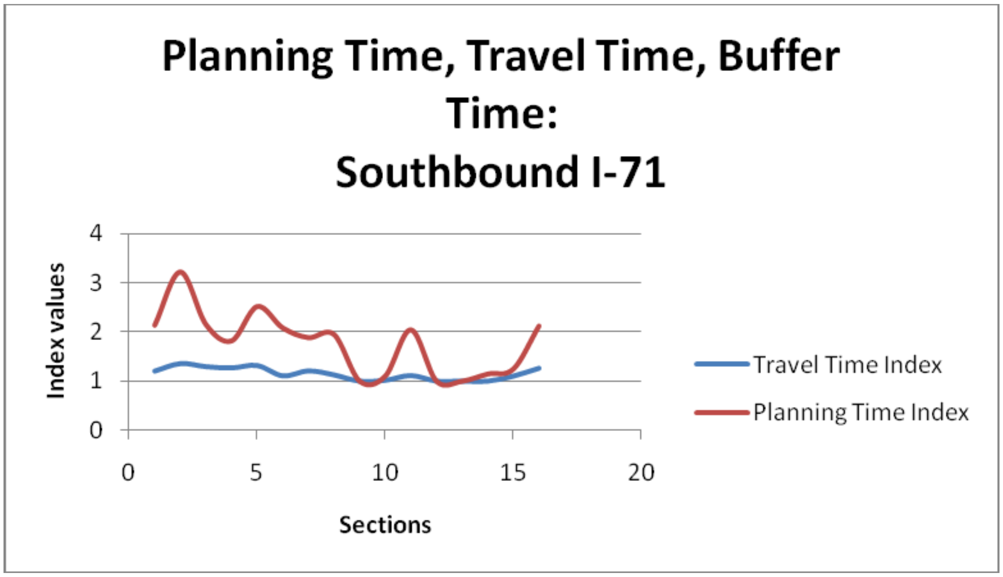


Figure 4 Planning Time, Travel Time and Buffer Time for SB I-71

Travel time reliability was determined by calculating the travel time index, planning time index and the buffer time index. This relationship is demonstrated in the graphs above and below.

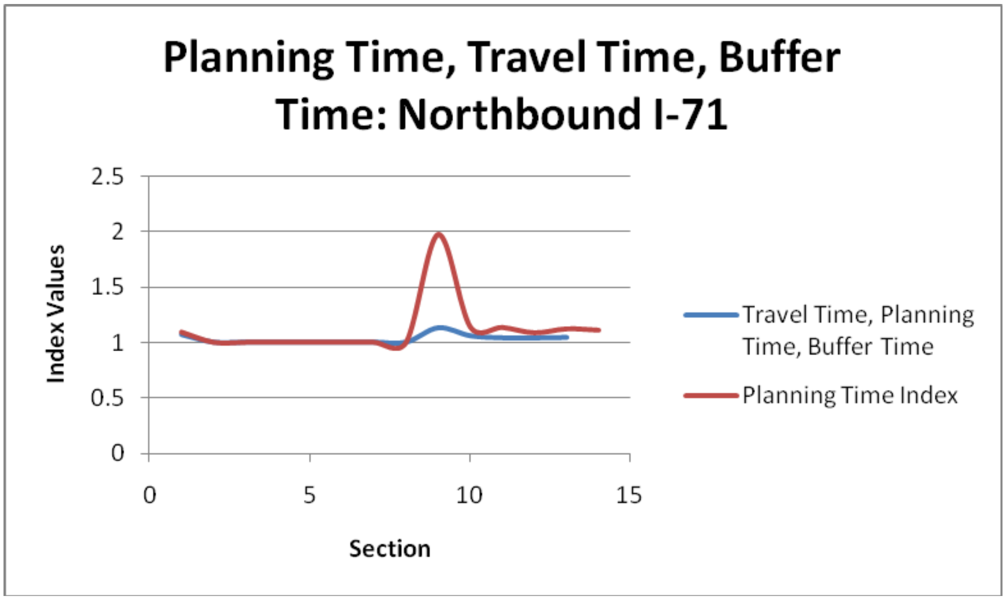


Figure 5 Planning Time, Travel Time and Buffer Time for NB I-71

HCS software was used to determine each segments LOS both north and southbound. The results of this analysis are shown in the table below.

Table 3 Level of Service for each segments SB I-71

Southbound	Distance (miles)	Description	Level of Service
segment 1	0.82	Exit 19 to Snider	D
segment 2	2.02	275 Interchange	D
segment 3	1.57	Pfeiffer Road	D
segment 4	1.68	Reagan, SR 126	D
segment 5	1.27	Montgomery Rd	D
segment 6	0.87	Kenwood Rd	D
segment 7	0.96	Stewart Rd	D
segment 8	1	Red Bank Rd	D
segment 9	1.91	SR 562	C
segment 10	0.97	Smith Edwards	C
segment 11	0.74	Dana Ave	C
segment 12	1.65	Montgomery Rd	B
segment 13	1.87	Taft	C
segment 14	0.6	Liberty	C
segment 15	0.49	71/50 split	C
segment 16	0.45	to finish	C

Table 4 Level of Service for each segments NB I-71

Northbound	Distance (miles)	Description	Level of Service
segment 1	0.98	Columbia	C
segment 2	0.61	Liberty	C
segment 3	0.53	Reading Rd	C
segment 4	0.93	Taft	C
segment 5	2.8	Montgomery Rd	C
segment 6	0.93	Smith Edwards	C
segment 7	0.97	SR 562	C
segment 8	0.58	Kennedy	D
segment 9	1.39	Red Bank Rd	D
segment 10	2.52	Stewart/Kenwood	A
segment 11	1.53	Reagan SR 126	A
segment 12	1.83	Pfeiffer Rd	A
segment 13	2.15	275 Interchange	A
segment 14	1.26	to Exit 19	A

The results of the LOS analysis confirm our segment reliability study using GPS data. The north bound section segment 9 rated a LOS D. The southbound section LOS is C and D over nearly every segment and validates the segment analysis of the GPS data. This justifies the directional buffer time differential.

The volume data was inputted into VISSIM traffic simulation software, which validated our GPS travel times. The results of this simulation may be found in Appendix II.

Table 5 VISSIM Simulation Travel Times Output

Time	Trav	#Veh	Trav	#Veh
VehC	All	All	All	All
No.:	1	1	2	2
Name	sb	sb	nb	nb
3600	97.9	4101	93.2	1446

No. 1 (sb) from link 2 at 382.2 ft to link 2 at 8492.6 ft Distance 8110.4 ft

No. 2 (nb) from link 1 at 232.6 ft to link 1 at 8318.7 ft Distance 8086.1 ft

6. CONCLUSIONS

The HCS analysis of the level of service yielded overall results stating that at the present time the level of service of I-71 between Exit 19 and the Ohio-Kentucky border is acceptable. However, some of the segments are the lowest acceptable rating for the level of service. Due to the level of service rating of C and D on various southbound sections of I-71, it is apparent that further study of segments 4 and 7 should be conducted to minimize the effects of current volume levels and improve the LOS rating. Future increase in volume along this section will result in a LOS rating falling below the acceptable rating of D. If I-71 experiences a substantial increase in volume the level of service would see the negative externalities.

When the level of service of a highway is worsened, the buffer time needed for commuters to arrive on time will experience an increase. This amounts to people having to plan extra time in their commutes, which would be an unfavorable condition for the commuters and residents of the affected areas. Further study of the level of service would be critical to determine some of the factors in the I-71 region that could have caused a change in the level of service. It is also critical to extrapolate the population growth for the area surrounding I-71 in order to try and predict any volume increases in the number of cars that will be using I-71 as their primary route of travel. Subsequently, it could reach the point where some sort of change would be necessary in order to continue to provide commuters with an acceptable level of service.

7. RECOMMENDATIONS

The data collection for this study took place from June 29, 2009 – July 9. The data was collected during the peak hours of 7am-9am. Because this study took place during the summer, we would believe that traffic would be heavier during the school year when teachers, students, and other professionals were also present on the highways. Also, non-peak hours were not recorded for this study, but would have been a useful comparison for the data recorded. The non-peak hours would have served as a base idea for the volume and correlating level of service. With more videotaping or volume counting with hand held Jamar traffic counters, more volume data could have been collected. More volume data would have allowed for more analysis of the videotapes and this would have allowed for a more precise calculate of the average volume of the highway.

Further recommended research would include study during other months of the year, and non-peak hours. It would also be recommended to continue the study over a longer period of time than several weeks. It would also be recommended to obtain data regarding a highway within close proximity, such as I-75. This would serve as a useful comparison for various highways in the region. This would also allow for some comparisons of the volume data for the two highways and some analysis of several qualities and characteristics of the roadways.

8. ACKNOWLEDGEMENTS

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10. APPENDIX I: RESEARCH SCHEDULE

June 23: Introduction and fundamental of HCS software

June 24: Lecture on travel time reliability

June 25: HCS software orientation

June 29: Field data collection

June 30: Field data collection

July 1: Filed data collection, development of presentation

July 2: Data extraction and analysis

July 6: Field data collection, VISSIM training

July 8: Field data collection

July 9: Field data collection

July 10: Data extraction and analysis

July 13: Data analysis

July 14: Data analysis

July 15: Data analysis, VISSIM training

July 16: Data analysis, development of presentation

July 17: Data analysis

July 20: Data analysis, and development of research poster

July 21: Data analysis

July 22: Development of research report and NSF report, Analysis using HCS software

July 23: Development of NSF report, research report, VISSIM simulation

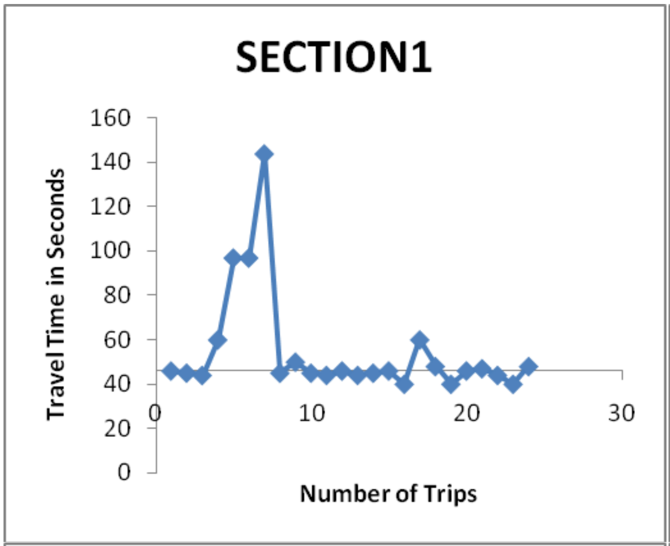
July 24: VISSIM simulation, development of research report

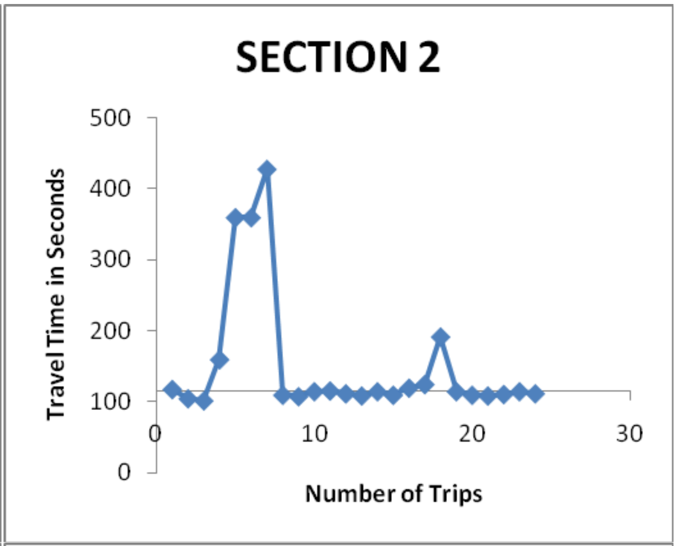
July 27: Development of research report, posters

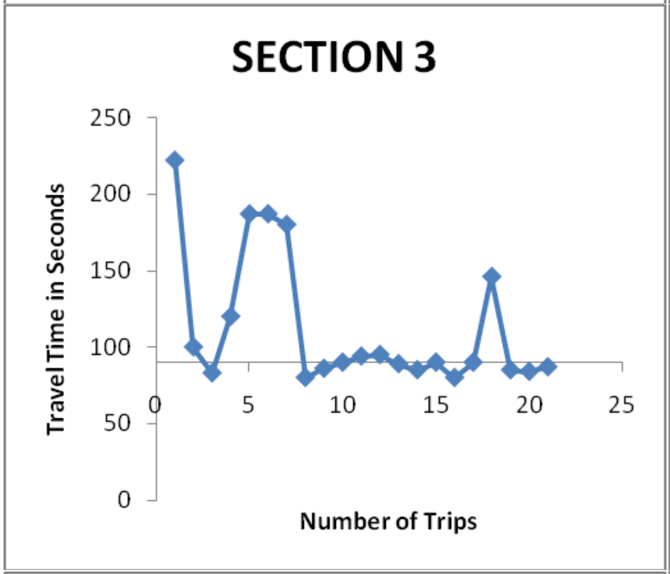
July 28: Finalization of research report, posters, presentation

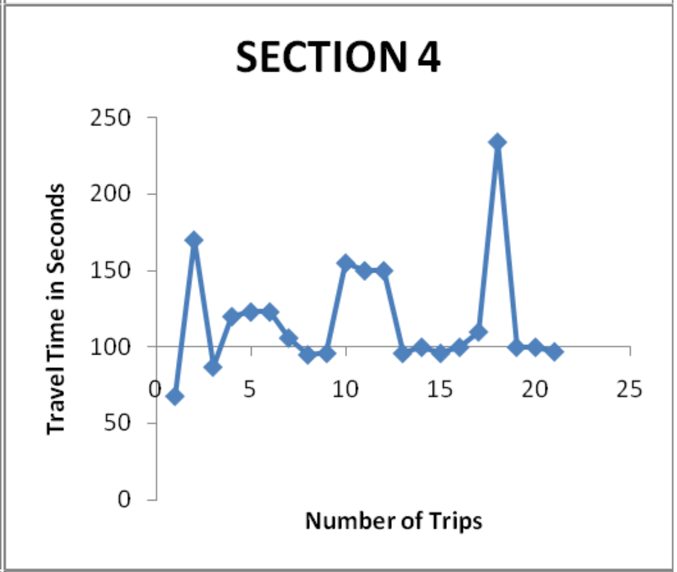
July 29: Finalization of presentation

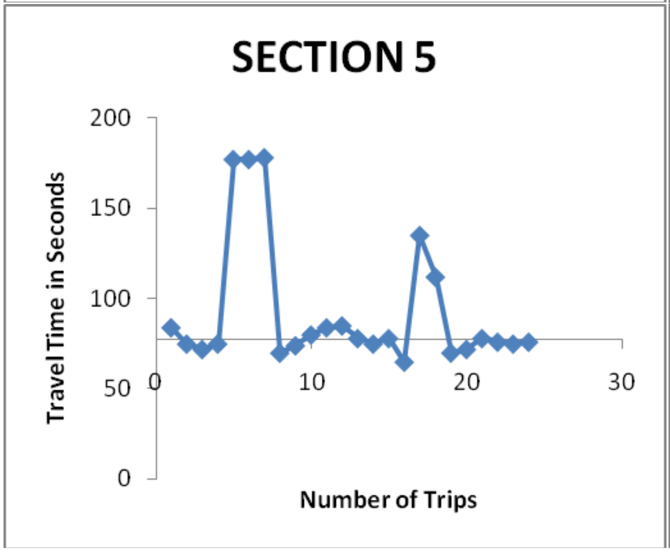
11. APPENDIX II











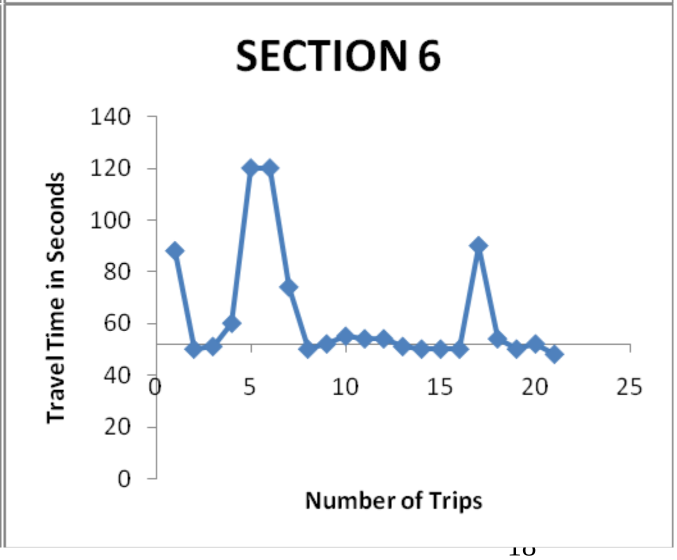


Figure 6-1 Travel Time Ranges for Southbound Sections

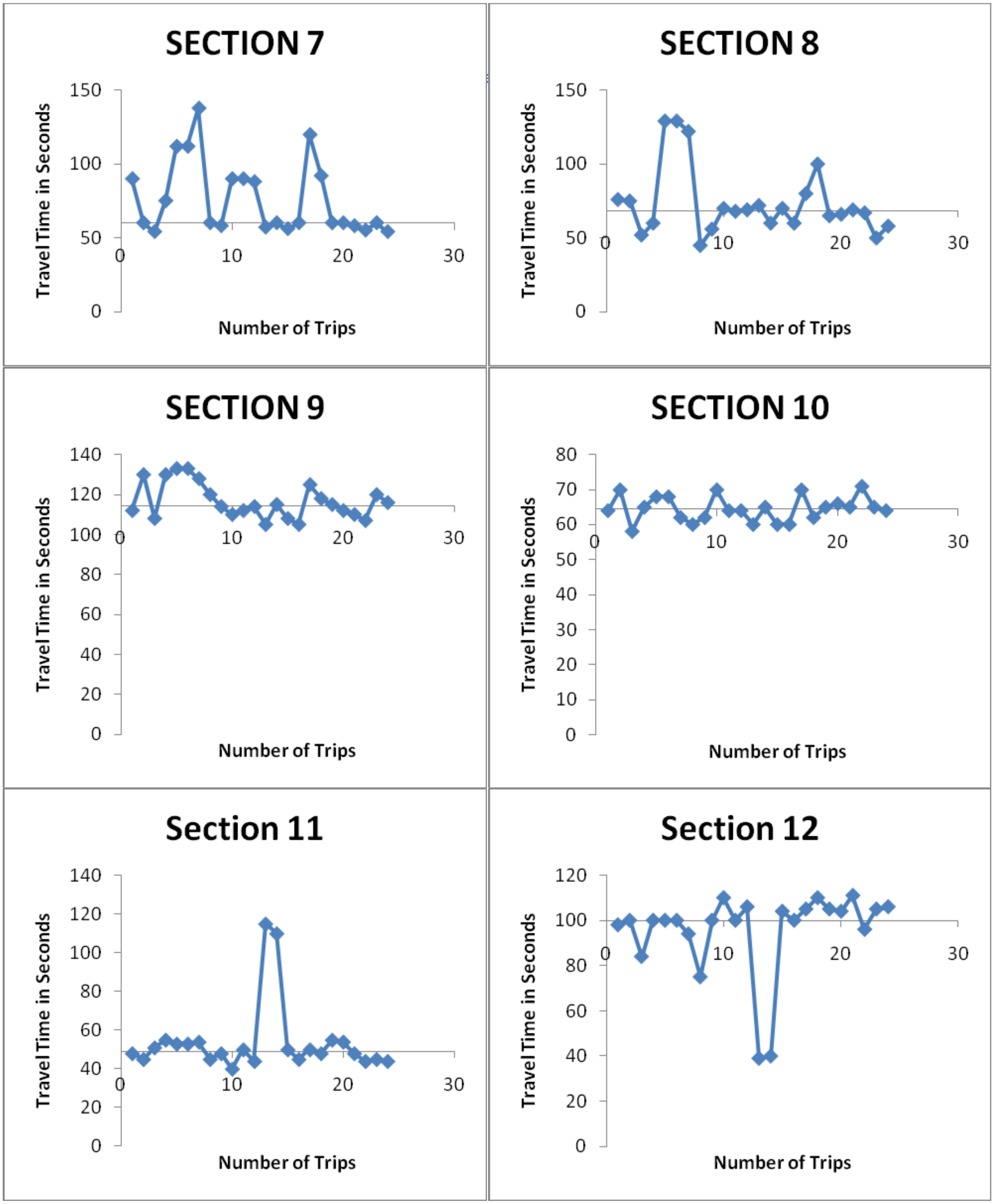


Figure 6-2 Travel Time Ranges for Southbound Sections

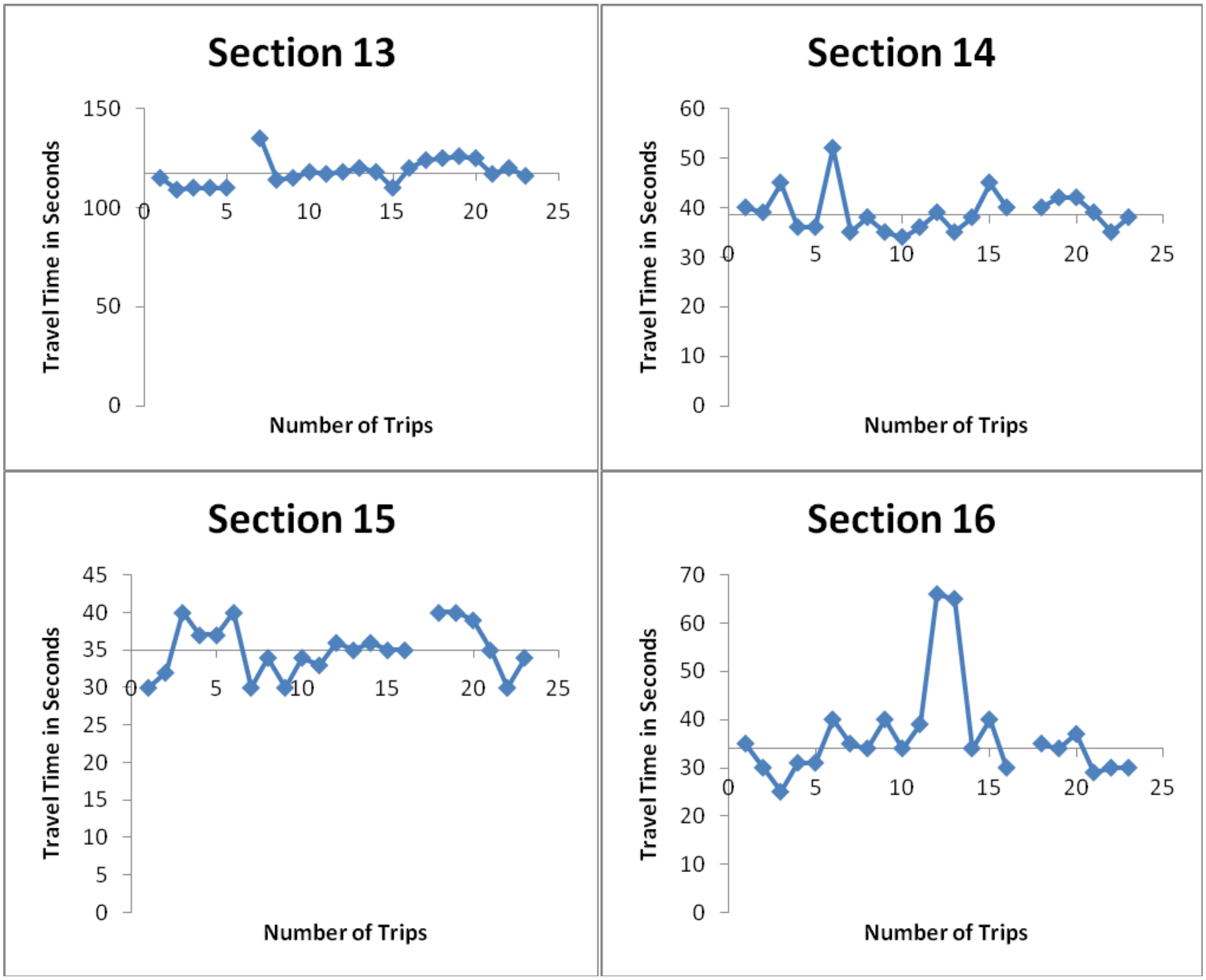


Figure 6-3 Travel Time Ranges for Southbound Sections

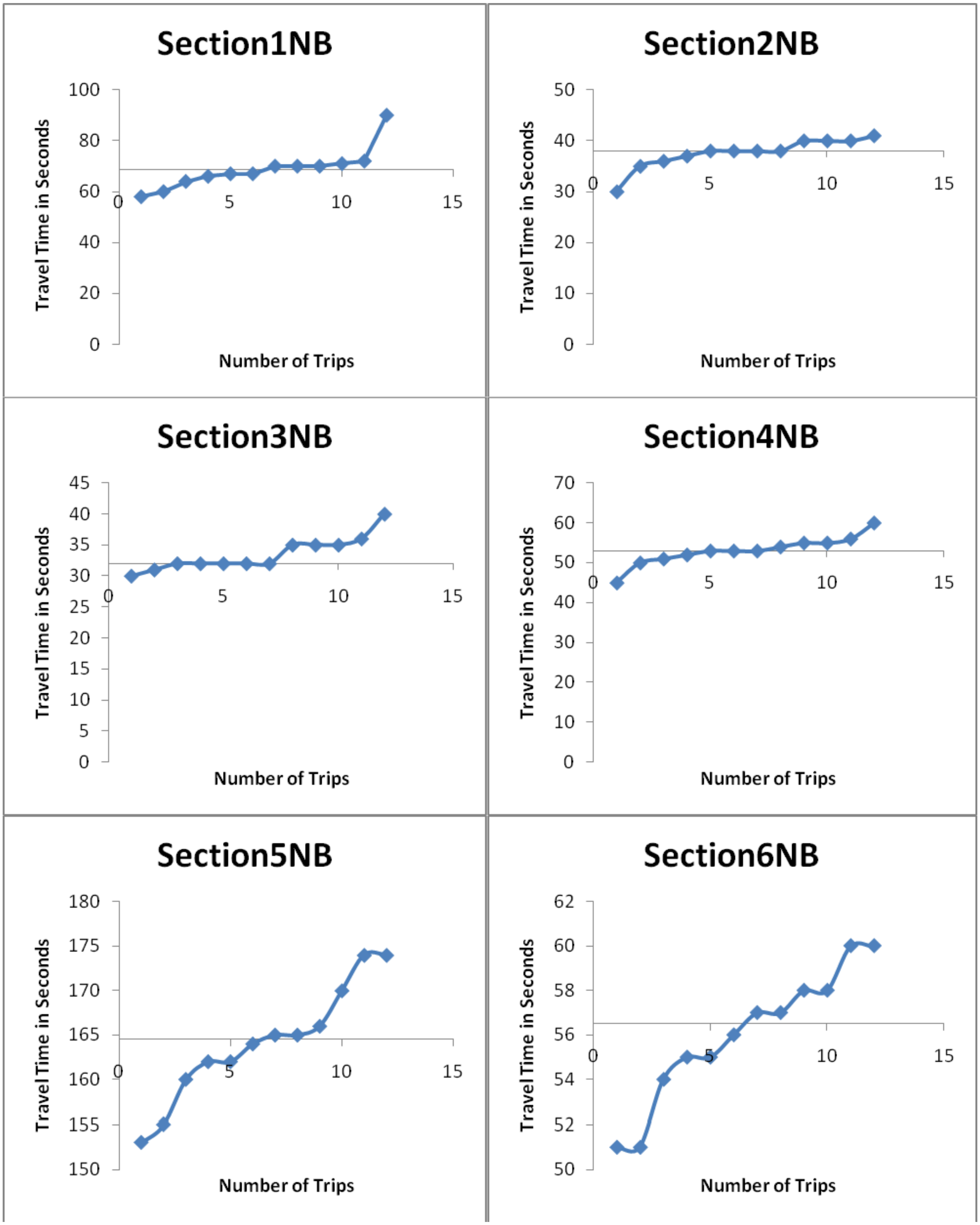


Figure 7-1 Travel Time Ranges for Northbound Sections

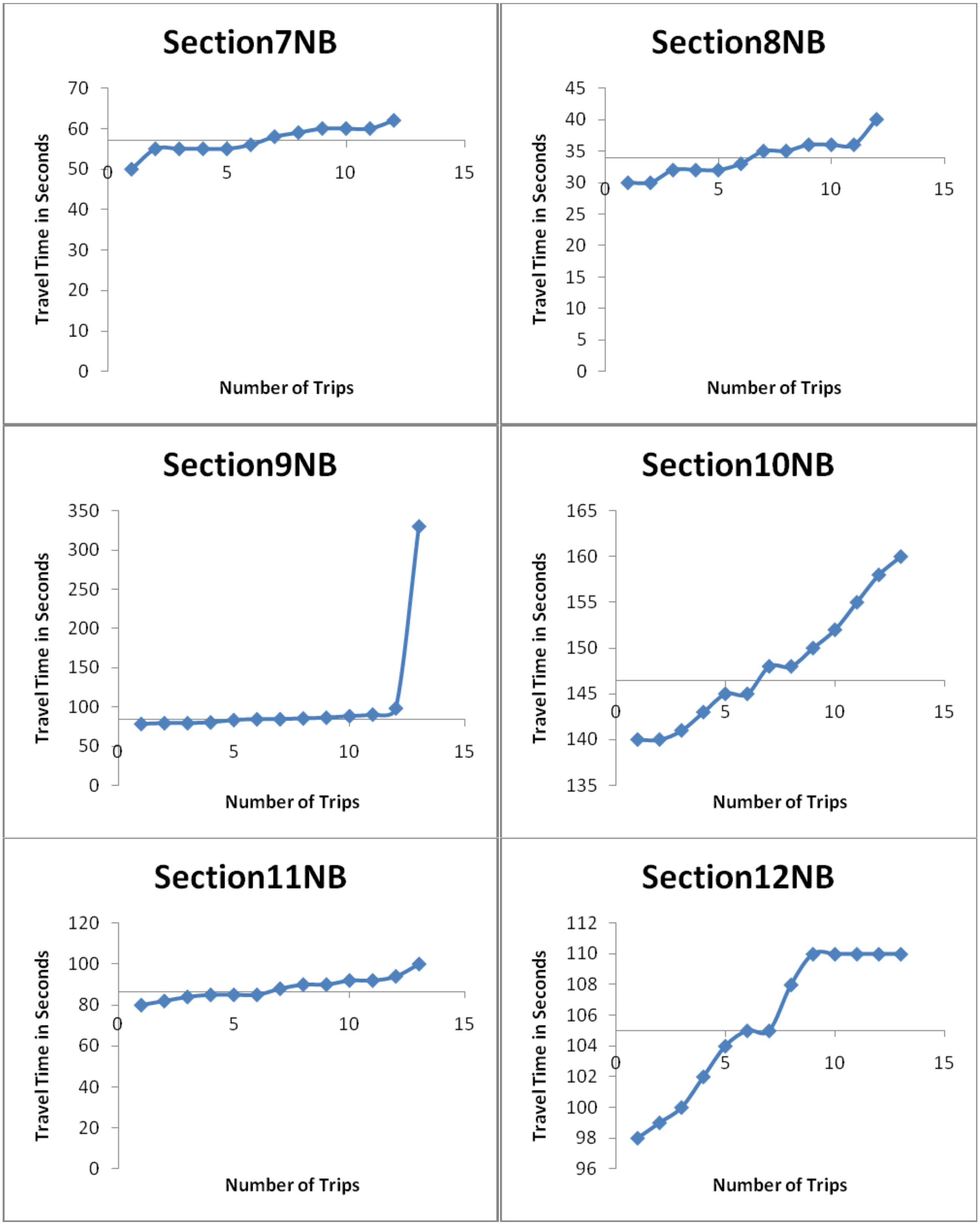


Figure 7-2 Travel Time Ranges for Northbound Sections

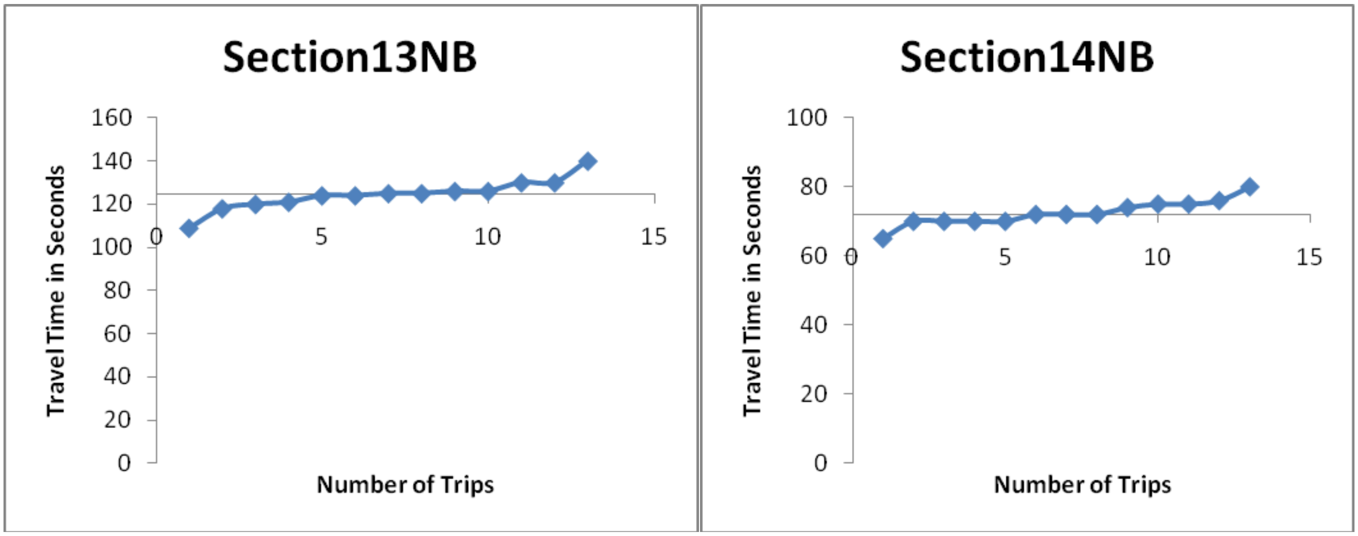


Figure 7-3 Travel Time Ranges for Northbound Sections

Table 6 Calculation spread sheet for Southbound I-75 segments

Sections/Trips	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	40	192	80	68	135	48	54	45	105	58	40	39	109	34	30	25
2	40	105	80	87	70	50	54	50	105	60	44	40	110	35	30	29
3	40	110	83	95	75	50	55	52	107	60	44	75	110	35	30	30
4	44	115	84	96	78	50	56	56	108	60	44	84	110	35	30	30
5	44	115	85	96	78	50	57	58	108	60	45	94	110	35	32	30
6	44	116	85	96	80	50	58	60	110	62	45	96	114	36	33	30
7	44	125	86	97	85	50	58	60	110	62	45	98	115	36	34	31
8	45	108	87	100	70	51	60	60	112	62	45	100	115	36	34	31
9	45	115	89	100	78	51	60	65	112	64	48	100	116	38	34	34
10	45	111	90	100	75	52	60	66	112	64	48	100	117	38	35	34
11	45	160	90	100	112	52	60	67	114	64	48	100	117	38	35	34
12	46	112	90	106	76	54	60	68	114	64	48	100	118	39	35	34
13	46	115	94	110	76	54	60	69	115	65	50	100	118	39	35	35
14	46	120	95	120	84	54	60	69	115	65	50	100	118	39	36	35
15	46	112	100	123	75	55	75	70	116	65	50	104	120	40	36	35
16	47	109	120	123	72	60	88	70	118	65	51	104	120	40	37	37
17	48	110	146	150	75	74	90	72	120	65	53	105	120	40	37	39
18	48	102	180	150	65	88	90	75	120	66	53	105	124	42	39	40
19	50	118	187	155	84	90	90	76	125	68	54	105	125	42	40	40
20	60	109	187	170	72	120	92	80	128	68	54	106	125	45	40	40
21	60	110	222	234	74	120	112	100	130	70	55	106	126	45	40	65
22	97	360			177		112	122	130	70	55	110	135	52	40	66
23	97	360			177		120	129	133	70	110	110	n/a	n/a	n/a	n/a
24	144	428			178		138	129	133	71	115	111				
sum	1311	3637	2360	2476	2221	1323	1819	1768	2800	1548	1294	2292	2592	859	772	804
90 % number value	21.6	21.6	18.9	18.9	21.6	18.9	21.6	21.6	21.6	21.6	21.6	21.6	19.8	19.8	19.8	19.8
90%	82.2	260	176.6	150	135.8	86.6	112	113.2	130	70	55	108.4	125	44.4	40	40
95% number value	22.8	22.8	19.95	19.95	22.8	19.95	22.8	22.8	22.8	22.8	22.8	22.8	20.9	20.9	20.9	20.9
95%	97	360	187	169.25	177	118.5	118.4	127.6	132.4	70	99	110	125.9	45	40	62.5
actual avg time	54.625	151.5417	112.381	117.9048	92.54167	63	75.79167	73.66667	116.6667	64.5	53.91667	95.5	118.2381	39.28571	35.33333	37.09524
buffer time	42.375	208.4583	74.61905	51.34524	84.45833	55.5	42.60833	53.93333	15.73333	5.5	45.08333	14.5	7.661905	5.714286	4.666667	25.40476
index %	0.775743707	1.375584	0.663983	0.435481	0.912652	0.880952	0.562177	0.732127	0.134857	0.085271	0.836167	0.151832	0.064801	0.145455	0.132075	0.684852
speed lmt	65	65	65	65	65	55	55	55	55	55	55	55	55	55	55	55
seg length mi.	0.82	2.02	1.57	1.68	1.27	0.87	0.96	1	1.91	0.97	0.74	1.65	1.87	0.6	0.49	0.45
travel time free flow sec	45.41538462	111.8769	86.95385	93.04615	70.33846	56.94545	62.83636	65.45455	125.0182	63.49091	48.43636	108	122.4	39.27273	32.07273	29.45455
delay time	9.209615385	39.66474	25.42711	24.85861	22.20321	6.054545	12.9553	8.212121	0	1.009091	5.480303	0	0	0.012987	3.260606	7.640693
travel time index	1.202786247	1.354539	1.292421	1.267164	1.315662	1.106322	1.206175	1.125463	1	1.015893	1.113144	1	1	1.000331	1.101663	1.259406
planning time index	2.135840108	3.217822	2.150566	1.81899	2.516404	2.080939	1.884259	1.949444	1	1.10252	2.043919	1	1	1.145833	1.247166	2.121914
average speed	54.04118993	47.9868	50.29322	51.29564	49.40477	49.71429	45.59868	48.86878	58.93714	54.13953	49.40958	62.19895	56.93596	54.98182	49.92453	43.67137
speeds for HCS	55	55	55	55	55	55	55	55		55	55			55	55	55

Table 7 Calculation spread sheet for Northbound I-75 segments

Northbound I-71																				
			Sections																	
		Trips	1	2	3	4	5	6	7	8	9	10	11	12	13	14				
	1	1	58	30	30	45	153	51	50	30	78	140	80	98	109	65				
	2	2	60	35	31	50	155	51	55	30	79	140	82	99	118	70				
	3	3	64	36	32	51	160	54	55	32	79	141	84	100	120	70				
	4	4	66	37	32	52	162	55	55	32	80	143	85	102	121	70				
	5	5	67	38	32	53	162	55	55	32	83	145	85	104	124	70				
	6	6	67	38	32	53	164	56	56	33	84	145	85	105	124	72				
	7	7	70	38	32	53	165	57	58	35	84	148	88	105	125	72				
	8	8	70	38	35	54	165	57	59	35	85	148	90	108	125	72				
	9	9	70	40	35	55	166	58	60	36	86	150	90	110	126	74				
	10	10	71	40	35	55	170	58	60	36	88	152	92	110	126	75				
	11	11	72	40	36	56	174	60	60	36	90	155	92	110	130	75				
	12	12	90	41	40	60	174	60	62	40	98	158	94	110	130	76				
	13	13									330	160	100	110	140	80				
	Median		68.5	38	32	53	164.5	56.5	57	34	84	146.5	86.5	105	124.5	72				
95th Percentile			11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	12.35	12.35	12.35	12.35	12.35	12.35				
			70	40	35	55	174	60	60.8	37.6	179.2	158.7	96.1	110	133.5	77.4				
Actual Average Time			68.75	37.58333	33.5	53.08333	164.1667	56	57.08333	33.91667	103.3846	148.0769	88.23077	105.4615	124.4615	72.38462	1146.083	19.10139	6.0834	19 min 6 s
Average Speed			51.31636	58.43016	56.95522	63.07064	61.40102	59.78571	61.17372	61.56265	48.40179	61.26545	62.4272	62.46827	62.18789	62.66525				
Buffer Time			1.25	2.416667	1.5	1.916667	9.833333	4	3.716667	3.683333	75.81538	10.62308	7.869231	4.538462	9.038462	5.015385	141.2167	2.353611	21.21666	2 min 21 s
Buffer Time Index			0.018182	0.064302	0.044776	0.036107	0.059898	0.071429	0.065109	0.1086	0.733333	0.07174	0.089189	0.043034	0.072621	0.069288				
Speed Limit			55	55	55	55	55	55	55	55	55	65	65	65	65	65				
Segment Length			0.98	0.61	0.53	0.93	2.8	0.93	0.97	0.58	1.39	2.52	1.53	1.83	2.15	1.26				
Travel Time Free Flow			0.017818	0.011091	0.009636	0.016909	0.050909	0.016909	0.017636	0.010545	0.025273	0.038769	0.023538	0.028154	0.033077	0.019385				
Min			64.14545	39.92727	34.69091	60.87273	183.2727	60.87273	63.49091	37.96364	90.98182	139.5692	84.73846	101.3538	119.0769	69.78462				
Delay Time			4.604545	0	0	0	0	0	0	0	12.4028	8.507692	3.492308	4.107692	5.384615	2.6				
Travel Time Index			1.071783	1	1	1	1	1	1	1	1.136322	1.060957	1.041213	1.040528	1.04522	1.037257				
Planning Time Index			1.09127	1	1	1	1	1	1	1	1.969624	1.13707	1.134078	1.085307	1.121124	1.109127				

12. APPENDIX III: HCS Reports

13. APPENDIX IV: MAPs