EXPLORING RELATIONSHIPS BETWEEN TRAVEL TIME BASED PERFORMANCE MEASURES

by

Krupanidhi Koilada

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Approved by:

_____

Dr. Srinivas S. Pulugurtha

_____

Mr. David W. Naylor

_____

Dr. Venkata R. Duddu

ABSTRACT

KRUPANIDHI KOILADA. Exploring the Relationships Between Travel Time Based Performance Measures. (Under the guidance of DR. SRINIVAS S. PULUGURTHA)

Traffic congestion is a common problem on transportation networks in many urban areas. It causes delay, effecting the road users and their behavior. The road users always look to reduce their travel time and reach their destination on-time. Hence, travel time and travel time reliability are important performance measures in transportation research. Travel time variations are often observed and effected by various factors such as day-of-the-week (DoW), time-of-the-day (ToD), week-of-the-year (WoY), and speed limit. In the past, several researchers have explored the concept of reliability and proposed various measures for assessing transportation system performance and making informed decisions. However, they did not categorize and explore the relationships comprehensively by DoW, ToD, WoY, and speed limit. Therefore, the primary objective of this research is to categorize and explore the relationships between travel time based performance measures by DoW, ToD, WoY, and speed.

Raw time travel time data was obtained from the Regional Integrated Transportation Information System (RITIS) website at one-minute interval. The data for the years 2014 and 2015 was collected and processed to compute performance measures such as minimum, maximum, and average travel times; 10^{th}, 15^{th}, 50^{th}, 85^{th}, 90^{th}, and 95^{th} percentile travel times; buffer time (BT); buffer time index (BTI); planning time index (PTI); travel time index (TTI); and travel time variations based on 90^{th} and 80^{th} percentile travel times. The selected measures were computed using Microsoft SQL and were joined using Traffic Message Channel (TMC) ID with network data, to obtain the link length and

speed limit. The data was then sorted into 46 separate datasets to develop Pearson correlation matrices.

The results from the Pearson correlation coefficient analysis when the year was considered indicate that not much of variation in relationship between performance measures was observed. The relationship between travel time measures was same but slight variations were observed in the case of travel time reliability indices when analyzed by DoW. When analyzed by ToD, no variations were observed in case of travel time measures while variations were observed in case of travel time reliability indices. Likewise, when speed limit was considered, it can be observed that there are variations in relationships in case of travel time and reliability indices. Only a few variations were observed in case of travel time measures, while major variations were observed in case of travel time reliability indices.

DISCLAIMER

The views, opinions, findings, and conclusions reflected in this report are the responsibility of the authors only and do not represent the official policy or position of The University of North Carolina at Charlotte or other entity. The authors are responsible for the facts and the accuracy of the data presented herein. This report does not constitute a standard, specification, or regulation. The report does not endorse any equipment, product, vendor or private data source used in this research.

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LIST OF ABBREVIATIONS

ATT	average travel time
AVL	Automatic Vehicle Location
BT	buffer time
BTI	buffer time index
FHWA	Federal Highway Administration
MaxTT	maximum travel time
MinTT	minimum travel time
MSSQL	Microsoft Structured Query Language
PT	planning time
PTI	planning time index
RITIS	Regional Integrated Transportation Information System
SPSS	Statistical Package for Social Sciences
TMC	traffic message channel
TTI	travel time index
TTV	travel time variability

CHAPTER 1: INTRODUCTION

Traffic congestion is a common problem in many urban areas particularly, with the increasing demand for travel along with the population growth. In general terms, traffic congestion occurs when demand exceeds capacity i.e., when there are excessive number of vehicles on a stretch of road than it can handle at a particular time. This congestion leads to decrease in the vehicular speeds, which in turn increases the travel time. The census data shows that from the year 2010 to 2017, there was a 16% increase in population in the Mecklenburg County, NC. Similarly, the city of Charlotte, NC has seen, approximately, a 2%-2.5% population increase every year, since the year 2010. This clearly indicates that thousands of new vehicles are using the roads in an urban area like Charlotte, NC every year. This demands the need to expand the existing roads, construct new roads or identify solutions to better manage existing roads.

Traffic congestion is not just connected to the population growth. There are many other factors which cause traffic congestion and delay. These factors include traffic incidents, work zone activity, weather, special events, traffic control devices, amongst others. The most common traffic incidents include vehicular crashes, breakdown of vehicles, and debris on the travel lanes. Vehicular crashes are one of the common reasons for traffic congestion. Even a property damage only crash could lead to vehicle delay. It might not bring the traffic to a complete stop but may result in slow moving traffic. On the

other hand, the vehicular delay and complete stoppage of traffic could exceed 90 minutes in case of a fatal or severe injury crash.

The incidents which take place on travel lanes usually disrupt the normal flow of traffic by slowing down the speeds of the vehicles. In addition to the travel lanes events, incidents on the shoulder or roadside can cause congestion by distracting the road user (in particular, driver) which causes change in the normal traffic flow.

Work zones are other major events which cause traffic congestion. Construction activity usually results in physical changes such as lane closure, diversion, lane reduction, and road closure. These factors usually cause disruption to the normal flow of traffic. Weather condition usually effects the driver behavior causing congestion. Inclement weather condition such as heavy rain, snow-fall, fog, and smoke often effect the visibility of driver causing slowdown of regular traffic. Also, road surface condition effects the drivers, which reduces vehicle speeds causing congestion.

The fluctuations in normal traffic flow depends on time-of-the-day (ToD) and day-of-the-week (DoW). The traffic flow varies during specific times of the day and days of the week. For example, the traffic flow is higher during the peak hours (8am-9am; 5pm-6pm) than the off-peak hours (10am-11am; 9pm-10pm). Hence, traffic congestion occurs more during the peak hours. This is often referred to as recurring congestion. Similarly, the number of trips made on weekday are more compared to trips made during a weekend day. Therefore, there is a higher chance of congestion during weekdays compared to weekends. On the other hand, congestion also occurs due to special events like sporting events, musical concerts, and cultural events. These special events attract lots of traffic on the specific day of the event, causing huge disruption to the traffic flow. Traffic control devices

such as poorly maintained traffic signals and railroad crossings also cause congestion. If a road exceeds its maximum capacity of vehicles, it causes bottlenecks restricting the flow of traffic. Bottlenecks are a major issue for transportation engineers and were being studied because of their impact on the physical traffic flow.

Travel time increase due to traffic congestion. It varies by the ToD and DoW. The fluctuations in travel time causes swings in the road user experience, effecting when and how they choose to travel. The effect could vary by speed limit of the road section. The variations may be high on high speed roads compared to low speed roads.

1.1 Need for Research

Travel time performance measures such as average travel time (ATT), minimum travel time (MinTT), maximum travel time (MaxTT), 95^{th} percentile travel time, 90^{th} percentile travel time, 85^{th} percentile travel time, 50^{th} percentile travel time, 15^{th} percentile travel time, 10^{th} percentile travel time, and reliability measures such as buffer time (BT), buffer time index (BTI), travel time index (TTI), planning time index (TTI), and travel time variability were proposed and used to assess the performance of link or section of a road. Some researchers have examined the relationships between these travel time and travel time reliability measures and their applicability for various transportation assessment scenarios (ranking / prioritization, before-after analysis, etc.).

The traffic volume usually increases over time. In other words, traffic condition varies by year, and does not remain the same. Similarly, traffic volume and traffic condition varies by DoW and ToD. The traffic condition during a weekday (Monday to Friday) is usually different from weekend (Saturday and Sunday). Likewise, the traffic condition

during the peak hour traffic is different from off-peak hour traffic. It could also vary seasonally (winter, spring, summer, and fall) and during holiday weeks when compared to normal weeks.

The travel time may also be affected due to road characteristics, which are different for different road classifications. Among these factors, speed limit is one of the most important factor in any study. The relationships and applicability to a specific scenario may vary by speed limit. Different roads has different speed limits. Therefore, the travel time also varies, which makes the speed limit an important factor to study the relationships between travel time performance measures.

Overall, the relationships between travel time based measures may vary by year, DoW, ToD, week-of-the-year (WoY), and speed limit. Therefore, there is a need to study and understand the relationships between travel time based performance measures and how they vary by DoW, ToD, WoY, and speed limit. Understanding the relationships is important for identifying suitable performance measures and assessing transportation projects / alternatives.

1.2 Research Objectives

The key objectives of this research, therefore, are to categorize and explore the relationship between travel time based performance measures by Year, DoW, ToD, WoY, and speed limit.

It aims to address the following research questions.

1. Is there is a variation in relationships when analyzed by year?
2. Do the relationships vary by DoW and ToD?

3. Is there variation in relationships when analyzed by WoY?
4. Is there variation in relationships when analyzed by speed limit?

1.3 Organization of this Research

The rest of the report comprises of 4 chapters. Chapter 2 presents a review of literature related to travel time studies. Chapter 3 discusses the methodology adopted to conduct this research. Chapter 4 discusses the results from the computed Pearson correlation coefficients. Chapter 5 summarizes conclusions and provides recommendations for future work.

CHAPTER 2: LITERATURE REVIEW

Travel time reliability is an important concept and is expected to be widely adopted by practitioners. It is being researched widely in the recent years. Therefore, it is important to understand the literature behind the concept of travel time reliability in order to suggest suitable measures to quantify and assess or predict system performance.

2.1 Travel Time Estimation

Estimating the travel time is important from road user perspective as well as from practitioners' point of view. Travelers often expect to know the travel time from their origin to destination. Several researchers in the past have worked on estimating the travel time. Lucas et al. (2004) presented a new approach to estimate the travel time. Their study used second by second data collected from the detectors. The data collected was used to aggregate flow of vehicles and central tendencies to estimate the travel time of a segment. Single loop detector data was used by Guo and Jin (2006) to estimate the travel time using correlation analysis. A new average travel time estimation method was proposed for cross correlation analysis of traffic flow measurement.

Bhaskar et al. (2014) researched and discussed the problems arising with the spacing of loop detectors for travel time data collection. To address this issue, a hybrid model using the loop detector data was developed for travel time estimation. This model was found to be accurate in estimating the travel time under non-free flow conditions.

Another research using detectors for estimating the travel time was conducted by Ti and Williams (2015). To estimate the travel time accurately during congestion conditions, a modified dynamic traffic flow model was developed. The dynamic model was compared with simulation outputs to determine the accuracy of the flow model in estimating the travel time.

2.2 Travel Time Reliability

In the past, several reliability measures such as connectivity reliability (Iida and Wakabayashi, 1989), capacity reliability (Chen et al., 2002), travel demand satisfaction reliability (Lam and Zang, 2000), and travel time reliability (Asakura and Kashiwadani, 1991) were proposed. The capacity reliability proposed by Iida and Wakabayashi (1989), in their analysis, yielded travel time reliability as a byproduct. This research also provided methodology combining reliability and uncertainty analysis, network equilibrium models, sensitivity analysis, and Monte Carlo methods to assess the performance of degradable networks. Chen et al. (2002) introduced capacity reliability as a network performance index. The concept of travel demand satisfaction reliability was explored by Heydecker et al. (2007) to evaluate the performance of road network.

Travel time reliability is defined as the consistency or dependability of travel time measured in different times of a day on day to day basis (FHWA, 2006). Travel time reliability is preferred over other reliability measures. It has been an evolving concept, with several research efforts to identify the methods for the measurement of travel time reliability in recent years.

Travel time reliability is generally measured using heuristic and statistical methods. It as defined by Asakura and Kashiwadani (1991) as the probability of completing an

origin-destination trip in the specified time interval. Abdel-Aty et al. (1995) and Chen et al. (2002) focused on developing statistical models to measure the travel time reliability of transportation network. To estimate the travel time reliability, a reliability model was proposed by Zhen-Ping and Nicholson (1997). The algorithm for developing the reliability model was proposed using measures of reliability. Also, several algorithms for solving the reliability model were discussed. A new method was proposed by Haitham and Emam et al. (2006) to estimate travel time reliability under non-recurring conditions with degraded capacities.

Estimating the travel time reliability is important than the travel time itself for the road users (Lyman and Bertini, 2008). Therefore, they examined the use of measured travel time reliability indices to improve the real-time transportation management. Dong and Mahmassani (2009) introduced a methodology for online prediction of travel time reliability using probability of traffic breakdown. In their research, a discrete Markov chain was developed and its matrix was used in estimating travel time reliability and the delay associated with the traffic flow breakdown. Lee et al. (2016) estimated the route choice model to determine the values of travel time reliability. They studied the travel time reliability by accommodating the route choice behavior of road users into mixed logit framework for valuation.

Risk-taking behavior of road users was also studied in the past. Road users are not just interested in saving the travel time but also in reducing the travel time variability (Chen et al., 2002). Therefore, they researched on route choice models based using travel time reliability and their influence on the risk-taking behavior. Chen et al. (2003) examined the effect of incorporating travel time variability and risk-taking behavior in measurement of

travel time reliability and route choice of road users under demand and variations. Li et al. (2015) studied travel time reliability using stochastic dominance and risk-taking preference commonality. They observed how risk-taking behavior (risk neutrality, risk aversion, and risk aversion) would affect the travel time reliability.

Chen et al. (2010) developed stochastic multi-objective models to solve the uncertainty in network demand. Three stochastic models were formulated in bi-level programming to optimize solutions for problems against travel demand uncertainty. Likewise, a multi-state model for travel time reliability was developed by Guo et al. (2010) to advance model fitting and provide a connection between travel time and the underlying travel time state. The proposed multi-state model was observed to be superior to the single-mode travel time reliability models. The multi-state models were further explored by using skewed component distributions (Guo et al., 2012). Six models, single-state, gamma, lognormal and their skewed distributions, were compared to find a superior model. Guo et al. (2012) showed that lognormal model performed better compared to other models. It was found to be better for modelling travel time under moderate and heavy traffic conditions.

2.3 Travel Time Reliability Measures

Several travel time reliability measures were proposed and used in the past. Lognormal distributions were used to formulate several reliability measures (Pu, 2011). Although there were many reliability measures, 90^{th} or the 95^{th} percentile travel times were found to be the simplest measures of travel time reliability. BT and BTI are two travel time reliability measures which were recommended by the United States Department of Transportation (FHWA, 2006). The evaluation of reliability performance measures was

also studied by ToD, DoW, and WoY (Pulugurtha et al., 2015; Puvvala et al., 2015; Pulugurtha et al., 2016).

The minimum travel time is the shortest time taken, while the maximum travel time is the longest time taken to traverse through any link. The average travel time is the arithmetic mean of travel times observed along a link. It is an important measure and used to compute reliability measures like BT, BTI, acceptable travel time variation index (ATTV), and desirable travel time variation index (DTTV). PT or 95^{th} percentile travel time is the total time for which a trip is typically planned (to reach destination in a timely manner 95% of times). The PT is also called as first worst travel time, which is the sum of average travel time and BT.

The free flow travel time is the time taken to traverse any section of a road under free flow conditions. It is used compute PTI and TTI. BT is the extra time, which the road users add to the average travel time in order to reach the destination on time.

Table 1 summarizes various travel time reliability measures which were formulated and used by past researchers.

TABLE 1: Travel Time Reliability Measures (Pulugurtha and Duddu, 2014)

Index	**Measure / Equation**	**Index**	**Measure / Equation**
NCHRP (1998) Definition	Standard deviation of travel time	λ_{skew} (Van Lint et al., 2004)	$\frac{TT_{90} - TT_{50}}{TT_{50} - TT_{10}}$
AASHTO (2008) Definition	Probability on-time performance	λ_{Var} (Bogers et al., 2007)	$\frac{TT_{90} - TT_{10}}{TT_{50}}$
Buffer Time (BT) (Lomax et al., 2004)	$TT_{95} - TT_{Avg}$	Variability (Wakabayashi, 2010)	TT_{85}-TT_{15}
Buffer Time Index (BTI) (Lomax et al., 2004)	$\frac{TT_{95} - TT_{Avg}}{TT_{Avg}} \times 100$	Variability (Wakabayashi, 2010)	TT_{80}-TT_{20}
First worst travel time over a month (Wakabayashi & Matsumoto, 2012)	TT_{95}	Variability (Wakabayashi, 2010)	TT_{70}-TT_{30}
Second worst travel time over a month (Wakabayashi & Matsumoto, 2012)	TT_{90}	Acceptable Travel Time Variation Index (Wakabayashi, 2010)	$P(TT_{avg}+A\text{TTV})$
Planning Time (PT) (Wakabayashi & Matsumoto, 2012)	TT_{95}	Desired Travel Time Reduction Index (Wakabayashi, 2010)	$P(TT_{avg}-D\text{TTR})$
Planning Time Index (PTI) (Sisiopiku & Islam, 2012)	$\frac{TT_{95}}{TT_{free\ flow}}$	Travel Time Index (TTI) (Lyman & Bertini, 2008)	$\frac{TT_{avg}}{TT_{free\ flow}}$
Travel Time Variability (TTV) (Tu et al., 2007)	$TT_{90} - TT_{10}$	Frequency of Congestion (Lyman & Bertini, 2008)	Percent of days/periods that are congested
TranSystems Definition (2005)	Probability of on-time performance		

2. 4 Limitation of Past Research

Several researchers proposed and used various travel time and travel time reliability performance measures, and adopted travel time estimation methods in their research. The evaluation of travel time based performance measures and their relationships was also performed in the past. However, the evaluation of travel time based performance measures by year, DoW, ToD, and WoY was not comprehensively performed in the past.

Speed limit is an important factor for evaluating the relationship between performance measures. It varies on the transportation network and depends on prevailing geometric conditions (from a safety point of view). The functional classification of a road also depends on the speed limit. Each road functional classification has different road characteristics.

When the road characteristics differ, the relationships between the performance measures might differ. For example, when an interstate with higher speed limit is compared to an arterial street with relatively lower speed limit, there will be a difference in travel time even if the length traveled on the both roads is same. The travel time is lower on interstate when compared to an arterial road, in this case. When the speed limits or the road classifications are different, there is a variation in travel times, hence differences in computed travel time based performance measures. Therefore, this research focuses on categorizing data and evaluating the change in relationships between the travel time based performance measures by year, DoW, ToD, WoY, and speed limit.

CHAPTER 3: METHODOLOGY

To evaluate the operational performance of any link or corridor, travel time is an important measure. Travel time of road users has formed the basis for many transportation studies. As stated in the previous chapter, several travel time measures were proposed in the past. Understanding the relationships and applicability is important when evaluating the performance of a link or corridor. The computation of travel time performance measures depends on reliable data. The data sources, selection of study area, and analytical approach adopted is discussed in this chapter.

3.1 Probe Data

Data is an integral part of any research. The quality of research outputs depends on reliable data. Transportation research needs the most accurate and latest data to assess the problem pertaining to transportation network performance. Such data includes probe data.

Probes are the devices which are either carried by road users or vehicles. These devices can collect real-time data and transmit them at frequent refresh rates. Mobile applications, mobile phones, road sensors, automatic vehicle locations (AVL), and toll-tag technology usually act as probes for collecting the traffic data.

Mobile phones are important probe devices. With the growth of smart phones, there has been a phenomenal growth in the volume of probe data collected. This growth in probes makes it a reliably, large sample source of data.

In addition, there are several navigation mobile apps such as Uber, Lyft, Google maps, Waze and HERE maps. These apps collect the data such as origin-destination, travel time, speed, and location data by utilizing the global positioning system (GPS) in the mobile phone.

The AVL uses the GPS to track the vehicle and collect the vehicle travel information. The AVL technology is mainly used in public transit and trucking fleets. Since the reduction in the cost of AVL devices, they are further being installed at large scales in vehicle fleets like taxi, buses and long-haul trucks.

Both, mobile phone and AVL technology measure vehicle travel time, collect speed, and traffic volumes. Toll-tag is another method to collect the probe data. This technology is similar to the mobile phone and AVL technologies but need additional toll-tag readers on the right-of-way. These toll-tags were owned by road authorities, unlike the mobile phones and vehicle technology which were owned by road users.

Fixed point speed sensors, particularly loop detectors, were widely used to collect the traffic data. These sensors are being adopted widely due to lower costs and ease of installation. Overall, probe data has been a growing source of data due to its accuracy and value to researchers.

3.2 Regional Integrated Transportation Information System (RITIS)

RITIS is the leading data source used as data aggregation and data dissemination platform for solving complex transportation problems. RITIS database is used by thousands of researchers in planning, operations, research, the military and homeland security for developing smart, safe, secure and cost-effective mobility solutions. RITIS

creates many capabilities and insights, reduces the cost of planning activities and research, and eliminates the barriers between agencies for sharing information, coordination and collaboration (RITIS, 2018).

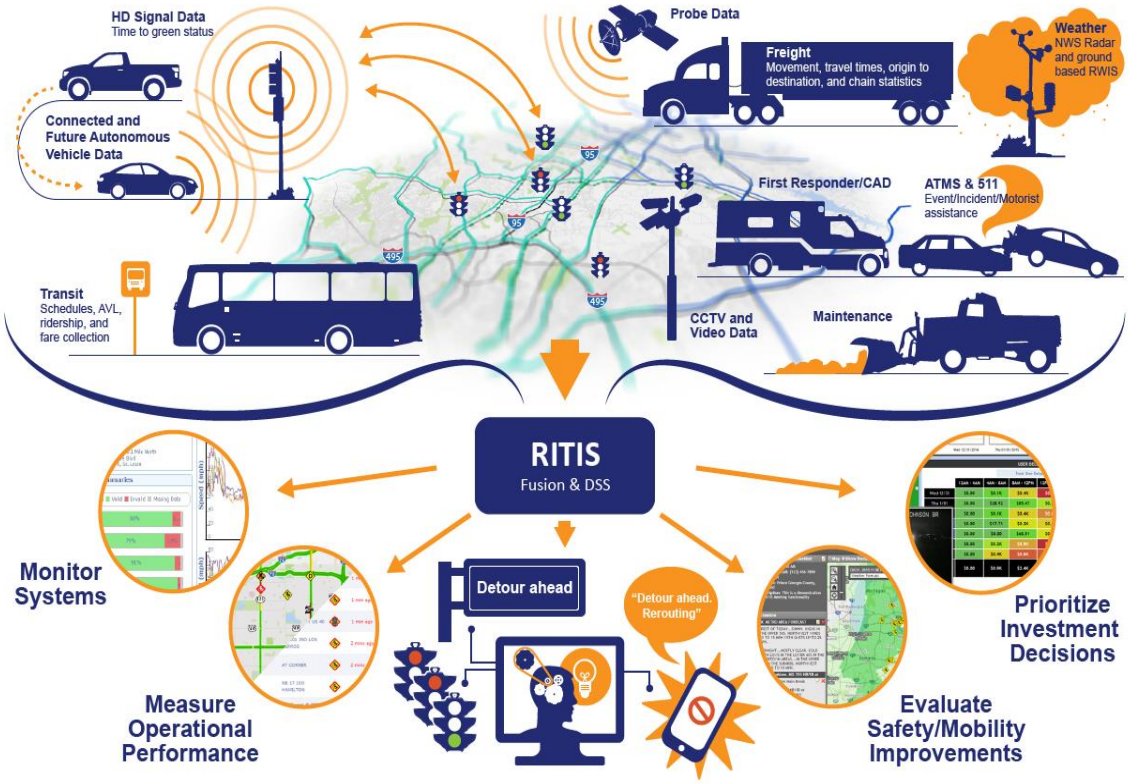


FIGURE 1: Working pattern of RITIS (Source: https://www.ritis.org/intro#ritis accessed on 12th July, 2018)

Figure 1 depicts the working pattern of RITIS database. As shown in the figure, RITIS integrates the data collected from various data sources such as transportation and public safety systems, the private sector, and military and probe devices such as AVL, mobile phones, and sensors. The data collected is then fused in secure cloud and then disseminated to users through websites, applications, and data feeds. The different data present in RITIS databases are listed next.

1. Traffic volume, travel time, speed, class and occupancy (from probe systems like Bluetooth, HERE, INRIX and TomTom technologies)
2. Event, work zone and incident information (from dynamic message signs and Highway Advisory Radio)
3. Crowdsourced Waze data (from public user data application called Waze)
4. Weather data (Roadway Weather Information Systems)
5. Managed lane status, signal status, device operational status
6. Surveillance video
7. Transit alert
8. Signal status, signal timing plans
9. Computer aided dispatch information
10. Static, descriptive information
11. Decision support response pans
12. Parking data
13. Freight movements
14. O-D and trajectory, and routing data

RITIS collects the data from almost every state with many transportation related measurements every day and fusions them. The data obtained from RITIS can be used to solve various transportation problems.

3.3 Selection of Links to Download Data

Figure 2 shows the screenshot of the RITIS website. The figure shows the map of places where the RITIS data was collected. To download the data, initially the location

where the data was required should be specified using the search tool. All the links for which the data were required could be selected. Once, the selection of links was performed, the date ranges are provided (days of week, and times of day). Further, the data sources and the measures required should be selected. Once all the required details were specified, the data can be downloaded for the selected links.

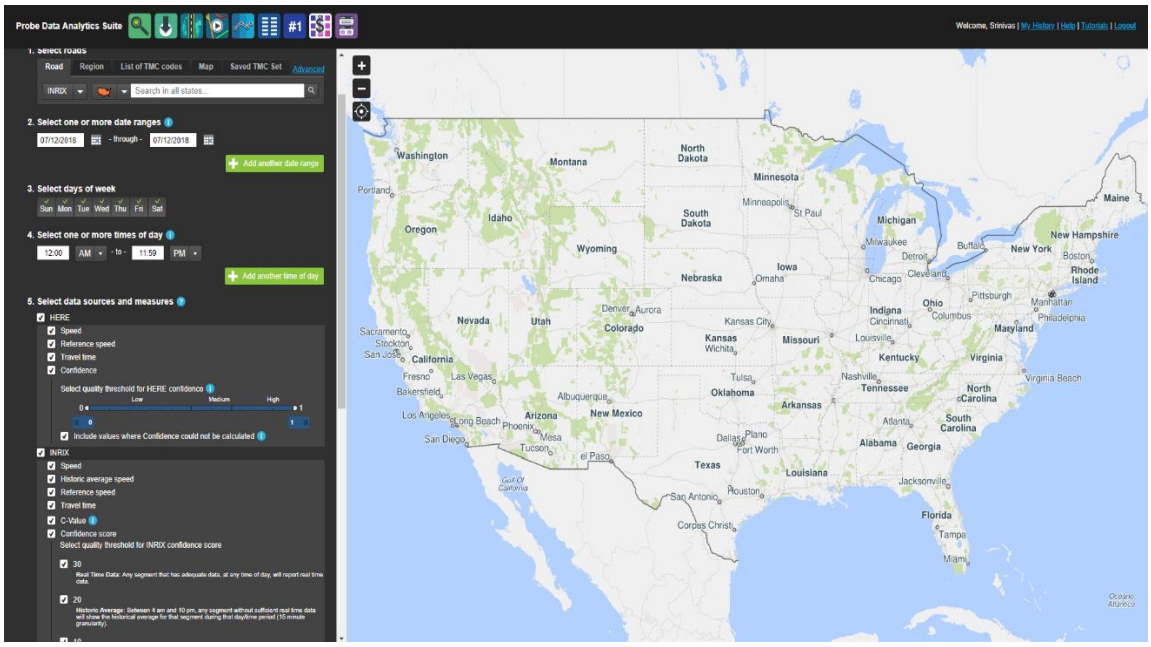


FIGURE 2: Screenshot of RITIS website

Figure 3 shows the TMC's for which the data was collected. They are located in the Mecklenburg County, North Carolina. For this study a total of 3290 TMC links were considered. Among the 3290 TMC's, 742 TMC's have speed limit of less than or equal to 35mph, 1822 TMC's have speed limit between 36mph – 45mph, 357 TMC's have speed limit between 46mph-55mph, and 370 TMC's have speed limit between 56mph-65mph. The data for these selected links was downloaded from RITIS website and used for this study.

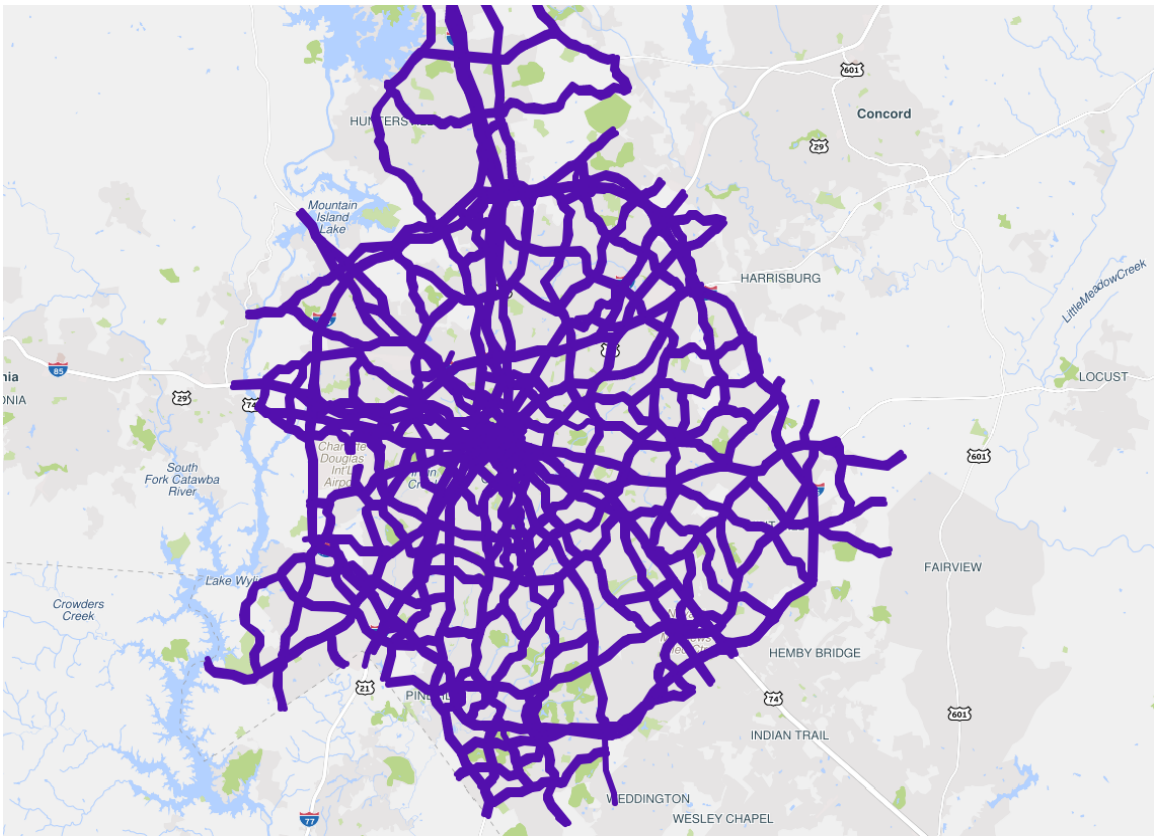


FIGURE 3: Screenshot showing the selected links

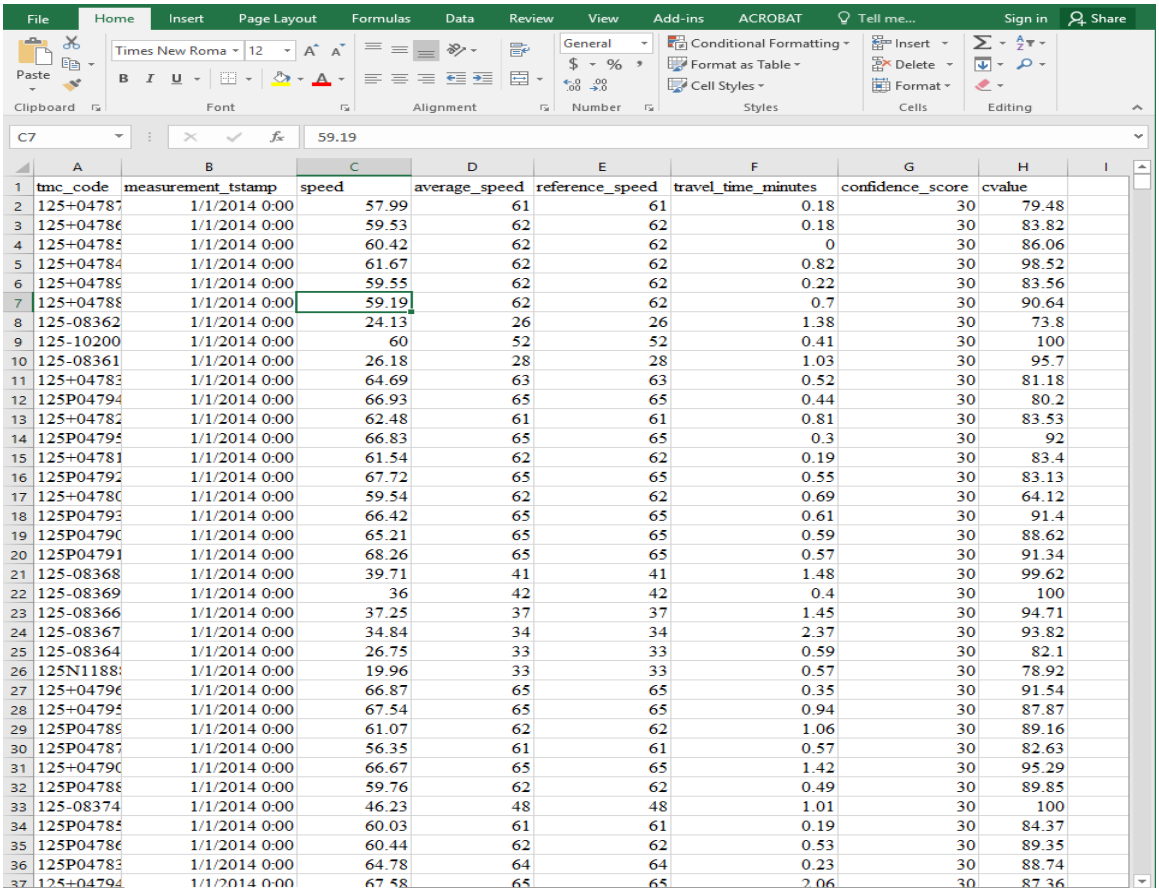
3.4 Travel Time Data

The data for this research was obtained from INRIX travel time database for the years 2014 and 2015. The travel time data obtained was for the entire Mecklenburg County, North Carolina for each link or Traffic Message Channel (TMC) in the transportation network. The travel time data contained contains the following set of variables.

1. Traffic Message Channel Code (tmc_code)
2. Measurement time stamp (measurement_tstamp)
3. Speed (speed)
4. Average speed (average_speed)

5. Reference speed (reference_speed)
6. Travel time (travel_time_minutes)
7. Score (confidence_score)
8. Value (cvalue)

Figure 4 shows the variables in the raw data obtained from INRIX.



tmc_code	measurement_tstamp	speed	average_speed	reference_speed	travel_time_minutes	confidence_score	cvalue
125+04787	1/1/2014 0:00	57.99	61	61	0.18	30	79.48
125+04786	1/1/2014 0:00	59.53	62	62	0.18	30	83.82
125+04785	1/1/2014 0:00	60.42	62	62	0	30	86.06
125+04784	1/1/2014 0:00	61.67	62	62	0.82	30	98.52
125+04789	1/1/2014 0:00	59.55	62	62	0.22	30	83.56
125+04788	1/1/2014 0:00	59.19	62	62	0.7	30	90.64
125-08362	1/1/2014 0:00	24.13	26	26	1.38	30	73.8
125-10200	1/1/2014 0:00	60	52	52	0.41	30	100
125-08361	1/1/2014 0:00	26.18	28	28	1.03	30	95.7
125+04783	1/1/2014 0:00	64.69	63	63	0.52	30	81.18
125P04794	1/1/2014 0:00	66.93	65	65	0.44	30	80.2
125+04782	1/1/2014 0:00	62.48	61	61	0.81	30	83.53
125P04795	1/1/2014 0:00	66.83	65	65	0.3	30	92
125+04781	1/1/2014 0:00	61.54	62	62	0.19	30	83.4
125P04792	1/1/2014 0:00	67.72	65	65	0.55	30	83.13
125+04780	1/1/2014 0:00	59.54	62	62	0.69	30	64.12
125P04793	1/1/2014 0:00	66.42	65	65	0.61	30	91.4
125P04790	1/1/2014 0:00	65.21	65	65	0.59	30	88.62
125P04791	1/1/2014 0:00	68.26	65	65	0.57	30	91.34
125-08368	1/1/2014 0:00	39.71	41	41	1.48	30	99.62
125-08369	1/1/2014 0:00	36	42	42	0.4	30	100
125-08366	1/1/2014 0:00	37.25	37	37	1.45	30	94.71
125-08367	1/1/2014 0:00	34.84	34	34	2.37	30	93.82
125-08364	1/1/2014 0:00	26.75	33	33	0.59	30	82.1
125N1188	1/1/2014 0:00	19.96	33	33	0.57	30	78.92
125+04796	1/1/2014 0:00	66.87	65	65	0.35	30	91.54
125+04795	1/1/2014 0:00	67.54	65	65	0.94	30	87.87
125P04789	1/1/2014 0:00	61.07	62	62	1.06	30	89.16
125P04787	1/1/2014 0:00	56.35	61	61	0.57	30	82.63
125+04790	1/1/2014 0:00	66.67	65	65	1.42	30	95.29
125P04788	1/1/2014 0:00	59.76	62	62	0.49	30	89.85
125-08374	1/1/2014 0:00	46.23	48	48	1.01	30	100
125P04785	1/1/2014 0:00	60.03	61	61	0.19	30	84.37
125P04786	1/1/2014 0:00	60.44	62	62	0.53	30	89.35
125P04783	1/1/2014 0:00	64.78	64	64	0.23	30	88.74
125+04794	1/1/2014 0:00	67.58	65	65	2.06	30	87.36

FIGURE 4: Screenshot showing the raw data obtained from INRIX

The description of each variable is provided next.

1. Traffic Message Channel Code - identity of the road segment
2. Time Stamp - the date and time the travel time was collected

3. Speed - estimated space mean speed for the road segment in miles per hour
4. Average speed - average mean speed for the road segment for that ToD and DoW
5. Reference Speed - free flow mean speed for road segment in miles per hour. It is the 85th percentile speed of the road segment.
6. Travel time - estimated travel time required to traverse the road segment
7. Score - 30 indicates real-time data; 20 indicates real-time data across multiple segments; 10 indicates historical data

3.5 Selected Performance Measures

The travel time and reliability measures which were selected and computed are discussed next. All these measures were considered in the analysis and their relationships were examined using Pearson correlation analysis.

1. Buffer Time (BT) – It is the extra time required in addition to the normal travel time. It is computed as the difference between the 95th percentile travel time and the average travel time.

$$\text{Buffer Time} = TT_{95} - TT_{ave}$$

2. Buffer Time Index (BTI) – It is the ratio of the difference between the 95th percentile and the average travel time to the average travel time.

$$\text{Buffer Time Index} = \frac{TT_{95} - TT_{ave}}{TT_{ave}} * 100$$

3. Planning Time Index (PTI) – It is the ratio of the 95th percentile travel time to the free flow travel time.

$$\text{Planning Time Index} = \frac{TT_{95}}{TT_{freeflow}}$$

4. Travel Time Index (TTI) – It is the ratio of the average travel time to the free flow travel time.

$$\text{Travel Time Index} = \frac{TT_{ave}}{TT_{freeflow}}$$

5. Travel Time Variation (TTV) – It is the difference between the percentile travel times.

$$\text{TTV90} = TT_{90} - TT_{10}$$

$$\text{TTV85} = TT_{85} - TT_{15}$$

6. Travel Time Percentiles – $TT_{95}, TT_{90}, TT_{85}, TT_{50}, TT_{15}, TT_{10}$
7. Average travel time (ATT), minimum travel time (MinTT), and maximum travel time (MaxTT).

3.6 Data Processing

The raw data obtained for the years 2014 and 2015 was analyzed and processed using MS Structured Query Language (SQL), MS Excel, and ArcGIS software. The data obtained for every minute was initially uploaded into Microsoft SQL to compute the performance measures. Queries were developed to compute various travel time measures such as minimum travel time, maximum travel time, average travel time, 10^{th}, 15^{th}, 50^{th}, 85^{th}, 90^{th}, and 95^{th} percentile travel times. A snapshot of processed data from the MS SQL is shown in Figure 5. Further, the data was joined with the TMC identification file which has the details of each TMC. Then, the minimum, maximum, average travel times and the percentile travel times were divided by their corresponding TMC length.

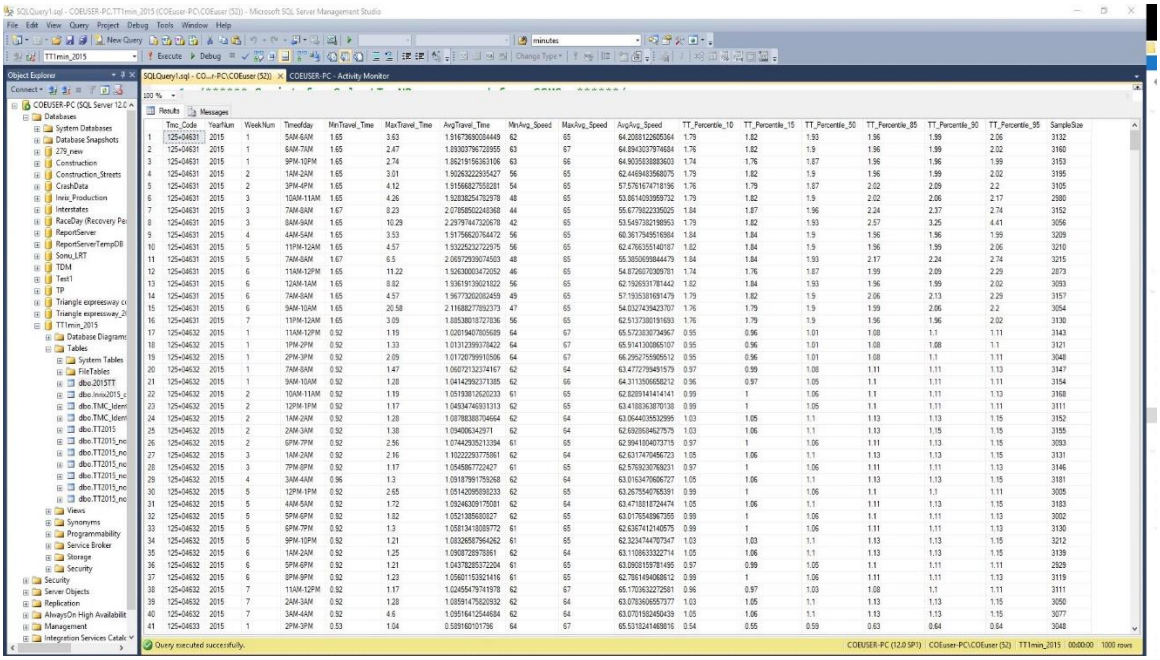


FIGURE 5: Screenshot showing the processed travel time data in Microsoft SQL

The processed data for the years 2014 and 2015 was then exported into MS Excel. The reliability measures such as BT, BTI, PTI, TTI, and travel time variations based on 90th and 85th percentile were computed. Once the reliability measures were computed, using ArcGIS, the travel time data was joined with TMC identification data by matching the TMC codes in both the datasets. Similarly, the new dataset was joined with the network file which consists of speed limit for each road segment. To reduce bias that might arise due to divided with small values, the new dataset was finally sorted by removing the links with less than 1/16th of mile (330 ft).

3.7 Datasets and Analysis

The final data set was again sorted into 59 separate datasets based on all the data combined, year, DoW, ToD, WoY, and speed limit. The data in each of the datasets varied

based on the year, DoW, ToD, WoY and speed limit. Following are the different criteria used to create 45 datasets.

- Based on year
    a. 2014
    b. 2015
- Based on DoW
    a. Wednesday
    b. Saturday
- Based on ToD
    a. Morning peak hour (8am – 9am)
    b. Afternoon peak hour (12pm – 1pm)
    c. Evening peak hour (5pm – 6pm)
    d. Off-peak hour (9pm – 10pm)
- Based on WoY
    a. Last week of January (winter)
    b. Last week of April (spring)
    c. Last week of July (summer)
    d. Last week of October (fall)
    e. Thanksgiving week compared to last week of October
- Based on speed limit category
    a. <=35mph
    b. 36mph – 45mph
    c. 46mph – 55mph

d. 56mph – 65mph

Statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) software (IBM SPSS, 2018). Pearson correlation matrices were developed using the 45 datasets to evaluate the relationships between travel time performance measures. To assess the relationship between the performance measures based on correlation coefficients, the following criteria was adopted.

1. Low Correlation: -0.3 to 0.3
2. Moderate Correlation: -0.7 to -0.3 or 0.3 to 0.7
3. High Correlation: <-0.7 or >0.7

CHAPTER 4: RESULTS AND DISCUSSION

Pearson correlation coefficient matrices are developed to examine relationships using each dataset. The Pearson correlation coefficients displayed in the tables indicate significance at a 95% confidence level. The value HP indicates positive high correlation (> 0.7), the value MP indicates positive moderate correlation (0.3 to 0.7), and the value LP indicates positive low correlation (0 to 0.3). Likewise, the value LN indicates negative low correlation (0 to -0.3), the value MN indicates negative moderate correlation (-0.3 to -0.7), and the value HN indicates negative high correlation (< -0.7).

Table 2 shows the correlation matrix for all the data combined. Table 2 shows that all the performance measures are correlated to each other, either positively or negatively. It can be observed that all the travel time measures (maximum travel time, minimum travel time, average travel time, 10^{th}, 15^{th}, 50^{th}, 85^{th}, 90^{th}, and 95^{th} travel time) are highly correlated with each other. On the other hand, the reliability measures such as BTI, PTI, and TTI are lowly correlated with the travel time measures and moderately correlated with each other. Likewise, BT and travel time variations based on 90^{th} and 85^{th} percentile travel times are moderately correlated with maximum travel time, minimum travel time, average travel time, 10^{th}, 15^{th}, and 50^{th} percentile travel times; BT is highly correlated with 95^{th} percentile travel time, TTV 90, and TTV 85; PTI is lowly correlated with TTI, TTV90 and TTV85.

TABLE 2: Pearson Correlation Coefficient Matrix: All Data Combined

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	MP	HP					
BTI	LN	LP	LN	LN	LN	LN	LN	LN	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LP	MP	HP			
TTI	LP	LN	LP	LP	LP	LP	LN	LN	LN	MN	MN	LN		
TTV90	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	HP

4.1 Correlation Matrices Based on Year

The traffic volume increases every year. Particularly, people migrate from rural areas to urban areas, which in turn increases the demand for travel and influences travel time based performance in urban areas. Therefore, studying the variations in relationships between performance measures based on data for different years is important.

Table 3 and Table 4 show the Pearson correlation matrices for the years 2014 and 2015. The Pearson correlation coefficient matrix for the year 2014 in Table 3 shows similar trends as the Pearson correlation coefficient matrix for all the data combined in Table 2. The travel time performance measures in Table 3 shows high correlations between each other. Likewise, the reliability measures such as BTI, PTI, and TTI had low correlation with travel time measures and low, moderate and high correlations with other reliability measures. Similarly, BT, TTV 90, and TTV 85 have shown similar correlations with travel time measures and mixed correlations with reliability measures. Among all the performance measures, only TTI and PTI were found not correlated to each other.

Table 4 shows the Pearson correlation coefficient matrix using data for year 2015. The relationship between performance measures were different in 2015 when compared to 2014. All the travel time measures, except the maximum travel time, are highly correlated to each other while the maximum travel time is moderately correlated with some travel time measures. Similar to the year 2014, BTI, PTI, and TTI are lowly correlated with travel time measures and are observed to have a mix of low, moderate and high correlations with reliability measures. The BT, TTV 90, and TTV 85 are moderately correlated with travel time measures and have mix of low, moderate, and high correlations with reliability

measures. Overall, it can be observed that the relationships between travel time based performance measures vary with change in the year.

TABLE 3: Pearson Correlation Coefficient Matrix: 2014

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	HP	HP					
BTI	LN	LP	LN	LN	LN	LN	LN	LN	LN	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LN	LP	HP			
TTI	LP	LN	LP	LP	LP	LP	LN	LN	LN	MN	MN	--		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LN	MN	HP

TABLE 4: Pearson Correlation Coefficient Matrix: 2015

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	LN	LP	LN	LN	LN	LN	LN	LN	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LP	MP	HP			
TTI	LP	LN	LP	LP	LP	LP	LP	LP	LN	MN	MN	LN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	MN	HP

4.2 Correlation Matrices Based on Day-of-the-Week (DoW)

The traffic volume on roads is not the same on all the days of the week. It varies on each day. Therefore, it is important to examine the change in relationships between the travel time based performance measures by DoW, particularly weekday and weekend. For studying the variations by DoW, the correlation matrices were developed using data for Wednesday (weekday) and Saturday (weekend).

Tables 5 and Table 6 show the Pearson correlation matrices for Wednesday and Saturday, respectively. From these two tables, it can be observed that the relationship between most of the performance measures is same for both the days of the week. The travel time measures are highly correlated with each other on both the days of the week. However, the relationship between the reliability measures were found to be slightly different for both the days of the week.

For example, BT is highly correlated with travel time measures such as maximum travel time, 85^{th}, 90^{th}, and 95^{th} percentile travel times during Wednesday, but moderately correlated during Saturday. Similarly, the BTI was observed to have a low correlation with minimum travel time on Wednesday, but moderate correlation on Saturday. Similar trends were observed in the case of PTI and TTI. In addition, on Wednesday, the BTI and PTI are not correlated with 90^{th} and 95^{th} percentile travel times. On Saturday, the BTI and TTI are not correlated with the maximum travel time. Although the travel time measures had shown similar relationships between each other on both the days, the reliability measures were found to have mixed correlations, varying from high correlation to low correlation between each other. Overall, the day-of-the-week was observed to have an effect only on reliability measures but not on the travel time measures.

TABLE 5: Pearson Correlation Coefficient Matrix: Wednesday

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	HP	HP					
BTI	LN	LP	LN	LN	LN	LN	LN	LN	LN	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LN	LP	HP			
TTI	LP	LN	LP	LP	LP	LP	LN	LN	LN	MN	MN	--		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LN	MN	HP

TABLE 6: Pearson Correlation Coefficient Matrix: Saturday

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	--	LN	LN	LN	LN	LN	LN	LN	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LN	MP	HP			
TTI	MP	--	LP	LP	LP	LP	LP	LP	LP	MN	MN	LN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	HP	HP	LP	LP	MN	HP

4. 3 Correlation Matrices Based on Time-of-the-Day (ToD)

The traffic volume is usually different during different hours of a day. Particularly, peak hour and off-peak hours are the times where large variation in traffic volumes are observed. Therefore, it is important to evaluate the relationship between travel time based performance measures by ToD. The Pearson correlation matrices ToD for Wednesday are shown in tables 7 to 10. Three peak hour time periods and one off-peak time period were considered for analysis and evaluation. The three peak hour time periods are 8am – 9am, 12pm - 1pm, and 5pm – 6pm, and the one off-peak time period is 9pm – 10pm.

Table 7 shows the Pearson correlation coefficient matrix for time interval between 8am – 9am. It can be observed that all the travel time measures are correlated with each other, except for the maximum travel time which is observed to be moderately correlated in few instances. The reliability measures are also correlated with each other but have mixed correlation patterns of low, moderate and high correlations. The reliability measures such as BTI, PTI and TTI are not correlated with travel time measures such as average travel time, 50^{th}, 85^{th}, 90^{th} and 95^{th} percentile travel times.

Table 8 shows the Pearson correlation coefficient matrix for time interval of 12pm - 1pm. Similar to Table 7, travel time measures are highly correlated with each other during this time interval. The reliability measures showed mixed level of correlations with each other. Likewise, the BTI, PTI and TTI are not correlated with travel time measures.

Table 9 and Table 10 show the Pearson correlation matrices for time intervals of 5pm – 6pm and 9pm – 10pm. In these two cases, similar relationships were observed within the travel time measures and are highly correlated with each other. In the case of reliability measures, variations in relationships were observed between the measures.

TABLE 7: Pearson Correlation Coefficient Matrix: Wednesday 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	LN	LP	LN	LN	LN	LN	--	--	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	LP	LN	--	LP	LP	--	LN	LN	LN	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 8: Pearson Correlation Coefficient Matrix: Wednesday 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	LN	LP	LN	LN	LN	LN	LN	LN	--	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	LP	--	LP	LP	LP	LP	--	--	--	MN	HN	MN		
TTV90	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 9: Pearson Correlation Coefficient Matrix: Wednesday 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	MN	LP	LN	LN	LN	LN	LN	--	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	--	LP	HP			
TTI	LP	LN	LP	LP	LP	LP	LN	LN	LN	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 10: Pearson Correlation Coefficient Matrix: Wednesday 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	--	LN	LN	LN	LN	LN	LN	LN	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	LP	MP	HP			
TTI	LP	LP	LP	LP	LP	LP	LP	--	--	MN	HN	MN		
TTV90	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	HP

Overall, from the correlation matrix, it was observed that travel time measures were correlated with each other and reliability measures were correlated with each other in all the four time periods. It was also observed that travel time measures were not correlated with reliability measures in a few instances. The travel time measures did not show much variation, while the reliability measures showed variations in the levels of correlated and uncorrelated measures with the change in time intervals.

The Pearson correlation matrices by ToD for Saturday are shown in tables 11 to 14. Similar to Wednesday, three peak hour time intervals and one off-peak hour time interval were used for analysis. All the four correlation matrices show that the travel time measures are correlated with each other, in all the time intervals. Travel time measures are found to be highly correlated with each other, except in one or two instances. However, reliability measures were found to be correlated with each other in all the four time intervals. The relationship between the reliability measures is consistent in all the four time intervals on Saturday, unlike a few variations that were observed on Wednesday. The relationship between the travel time measures and reliability measures has changed in a few instance with the change in time intervals. Overall, BTI, PTI, and TTI are the reliability measures which were found to be not correlated with travel time measures in most of the cases. The percentile travel times and average travel time are not correlated during the different time intervals on Wednesday, while the maximum travel time and 95^{th} percentile travel time are measures which are not correlated during four time intervals on Saturday.

TABLE 11: Pearson Correlation Coefficient Matrix: Saturday 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	--	LN	LN	LN	LN	LN	LN	LN	MP				
PTI	LN	--	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	MP	LP	LP	MP	MP	LP	LP	LP	LP	MN	HN	MN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	MN	HP

TABLE 12: Pearson Correlation Coefficient Matrix: Saturday 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	MN	--	LN	LN	LN	LN	LN	LN	--	MP				
PTI	LN	--	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	MP	--	LP	LP	LP	LP	LP	--	--	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	MP	HP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	LP	LP	MN	HP

TABLE 13: Pearson Correlation Coefficient Matrix: Saturday 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	MN	--	LN	MN	MN	LN	LN	LN	LN	MP				
PTI	LN	--	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	LP	--	LP	LP	LP	LP	LP	--	--	MN	HN	LN		
TTV90	MP	HP	MP	MP	MP	MP	MP	MP	HP	HP	MP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	HP	HP	LP	LP	MN	HP

TABLE 14: Pearson Correlation Coefficient Matrix: Saturday 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	LP	MP	MP	MP	MP					
BTI	MN	--	LN	LN	LN	LN	LN	LN	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	MP	LP	LP	MP	LP	LP	LP	LP	LP	LN	HN	LN		
TTV90	LP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	MN	
TTV85	LP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	LP	MN	HP

4.4 Correlation Matrices based on Week-of-the-Year (WoY)

The variations in traffic volume is not just affected by the DoW and ToD. It also varies by season and WoY. Seasonal variations should be studied to find out if there is any effect on the relationship between travel time based performance measures. To study the effect of seasonal variations and also the effect of WoY, data for one week of each season was used. The data was categorized into the following five datasets and was used to develop Pearson correlation matrices. The data for last week of January (winter), last week of April (spring), last week of July (summer), and last week of October (fall) was used to observe the effect of seasonal variations. Additionally, the data for the last of week of October and thanksgiving week was used to compare the effect of WoY (normal week compared to long weekend week). Tables 15 to 19 show the correlation matrices developed for the selected weeks of the year.

From the computed Pearson correlation matrices, it can be observed that the relationships between the travel time based performance measures is almost similar for the selected weeks of January, April and July. The correlation matrices of these three weeks show that the travel time measures are highly correlated in all the three matrices. The reliability measures are moderately correlated with each other in most cases and highly correlated in a few cases. The reliability measures such as BTI, PTI and TTI are lowly correlated with travel time measures, while the BT, TTV90 and TTV85 are moderately correlated with the travel time measures in all the three matrices. Likewise, in all the three matrices, 85^{th} percentile travel time is not correlated with BTI and TTI.

On the other hand, the Pearson correlation matrices for the last week of October and thanksgiving week are found to be similar. Although the relationships are mostly

similar to the last weeks of January, April and July, it was observed that there are few differences in the relationships related to reliability measures. Unlike the reliability measures in the case of January, April, and July (which are moderate and high correlations), a few relationships were observed to be of low correlation. Also, the 90^{th} percentile travel time is not correlated in the case of October and thanksgiving week. Overall, season and WoY are found to have a very minor effect on the relationships between travel time based performance measures.

TABLE 15: Pearson Correlation Coefficient Matrix: Last Week of January (Winter)

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	LP	LN	LN	LN	LN		LP	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP	HP			
TTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP	HN	HP		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	HP

TABLE 16: Pearson Correlation Coefficient Matrix: Last Week of April (Spring)

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	LP	LN	LN	LN	LN		LP	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP	HP			
TTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP	HN	HP		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	HP

TABLE 17: Pearson Correlation Coefficient Matrix: Last Week of July (Summer)

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	LP	LN	LN	LN	LN	LN	LP	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP	HP			
TTI	LN	LP	LN	LN	LN	LN	--	LP	LP	MP	HN	HP		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	MP	MP	HP

TABLE 18: Pearson Correlation Coefficient Matrix: Last Week of October (Fall)

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	--	LP	MP	HP			
TTI	LN	LP	LN	LN	LN	LN	LN	--	LP	LP	HN	HP		
TTV90	MP	HP	MP	MP	MP	MP	MP	HP	HP	HP	MP	LP	LP	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	LP	HP

TABLE 19: Pearson Correlation Coefficient Matrix: Thanksgiving Week

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	LN	LP	LN	LN	LN	LN	LP	LP	LP	MP				
PTI	LN	LP	LN	LN	LN	LN	LN	LP	LP	MP	HP			
TTI	LN	LP	LN	LN	LN	LN	LP	--	LP	LP	HN	HP		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	LP	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	MP	LP	MP	HP

4.5 Correlation Matrices Based on Speed Limit

Speed limit was not taken into consideration by most of the researchers in the past when exploring the concept of travel time reliability. Since, speed limit is an important factor in the case of travel speed and travel time, it should be considered to evaluate the differences in the relationships of the travel time performance measures. To study the influence of speed limit, Pearson correlation coefficient matrices were developed for the data which was categorized into four different datasets. Tables 20 to 23 shows the Pearson correlation matrices for speed categories <=35 mph, 36 - 45 mph, 46 - 55 mph and 56 - 65 mph for Wednesday. The Pearson correlation coefficients shown in these four tables indicate that the relationship between the performance measures varies with speed categories. Although most of the measures were correlated in all the tables, there were a few performance measures which are not correlated in the four cases. There uncorrelated performance measures were not the same in the Pearson correlation coefficient matrices. The number of uncorrelated performance measures also varied in each Pearson correlation coefficient matrix.

Table 20 shows the Pearson correlation coefficient matrix for Wednesday with speed limit category <=35 mph. In the case under <=35 mph, the BTI, PTI and TTI were not correlated with the maximum travel time. Similarly, TTI and PTI were not correlated with the 90^{th} percentile travel time and TTV 85.

Table 21 shows the Pearson correlation coefficient matrix for Wednesday with speed limit category 36 – 45 mph. Only BTI and PTI were not correlated with the maximum travel time, while all other performance measures were correlated with each other.

Table 22 shows the Pearson correlation coefficient matrix for Wednesday with speed limit category 46 - 55 mph. It can be observed that BTI was not correlated with the minimum travel time, 10^{th} and 15^{th} percentile travel time. Similarly, PTI was not correlated with the minimum travel time, 10^{th}, 15^{th} and 50^{th} percentile travel time.

Table 23 shows the Pearson correlation coefficient matrix for Wednesday with speed limit category 56 – 65 mph. It was observed that BTI, PTI, TTI are not correlated with the minimum travel time, while PTI is not correlated with 10^{th} and 15^{th} percentile travel times. Overall, from the Tables 20 to 23, it was observed that all the travel time measures are highly correlated with each other, except for the maximum travel time which was observed to be moderately correlated in a few instances. The reliability measures are observed to have variations in relationships with each other, with a mix of low, moderate, and high levels of correlations in all the four tables.

It can also be seen that the relationships between the performance measures varied for each of the speed limit category. Unlike the DoW, where the relationship between the travel time measures was constant in all cases, the relationship between a few travel time measures varied in all the four cases with change in speed limit category. In addition, differences by speed limit category was mainly observed with the reliability measures, as the relationships varied in most of the cases.

TABLE 20: Pearson Correlation Coefficient Matrix: Wednesday <=35mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	MN	--	LN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	--	LN	MN	MN	LN	LN	LN	LN	LP	HP			
TTI	MP	--	LP	MP	MP	LP	LP	LP	--	MN	MN	LN		
TTV90	MP	HP	HP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	HP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	HP

TABLE 21: Pearson Correlation Coefficient Matrix: Wednesday 36 - 45 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	HP	HP					
BTI	MN	--	MN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	--	MN	MN	MN	MN	LN	LN	LN	LP	HP			
TTI	MP	LN	LP	MP	MP	LP	LP	LP	LP	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	HP

TABLE 22: Pearson Correlation Coefficient Matrix: Wednesday 46 - 55 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	MP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	--	MP	LP	--	--	LP	MP	MP	MP	MP				
PTI	--	MP	LP	--	--	--	LP	LP	LP	MP	HP			
TTI	LN	MN	MN	LN	LN	LN	MN	MN	MN	MN	HN	MN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 23: Pearson Correlation Coefficient Matrix: Wednesday 56 - 65 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	MP	HP	HP	HP	HP	HP								
TT90	MP	HP	HP	MP	HP	HP	HP							
TT95	MP	HP	HP	MP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	--	MP	MP	LP	LP	LP	MP	MP	MP	MP				
PTI	--	MP	LP	--	--	LP	LP	LP	MP	MP	HP			
TTI	--	MN	MN	LN	LN	LN	MN	MN	MN	MN	MN	LN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	LP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	HP

Tables 24 to 27 show the Pearson correlation coefficient matrices for speed categories <=35 mph, 36 - 45 mph, 46 - 55 mph and 56 - 65 mph for Saturday. The correlations shown in the tables are similar in most of cases. Only a few performance measures are not correlated with each other. Most of the travel time measures are highly correlated with each other, while the reliability measures are lowly, moderately and highly correlated with each other.

Table 24 shows the Pearson correlation coefficient matrix for Saturday with speed limit category <=35 mph. In the case of <=35 mph, only PTI was observed to be not correlated with the maximum travel time, 95^{th} percentile travel time, and TTV 85. Table 25 shows the Pearson correlation coefficient matrix for Saturday with speed limit category of 36 - 45 mph. Table 25 shows that only PTI is not correlated with TTV 90, while all other performance measures are correlated with each other.

Table 26 shows the Pearson correlation coefficient matrix for Saturday with speed limit category of 46 – 55 mph. In this case, BTI and PTI are not correlated with the minimum travel time. Also, PTI was found not correlated with 10^{th}, 15^{th}, and 50^{th} percentile travel times and TTI. Table 27 shows the Pearson correlation coefficient matrix for Saturday with speed limit category of 56 - 65 mph. It can be observed, BTI, PTI and TTI are not correlated with the minimum travel, 10^{th}, 15^{th}, and 50^{th} percentile travel times. The TTI was also not correlated with maximum and average travel times.

Overall, from above set of Pearson correlation coefficient matrices for, both, Wednesday and Saturday, it can be observed that the relationship between performance measures are different when same speed categories are compared. The differences are not just confined to speed categories but to the DoW as well.

TABLE 24: Pearson Correlation Coefficient Matrix: Saturday - <=35mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	MN	LN	MN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	--	LN	MN	MN	LN	LN	LN	--	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN	LN		
TTV90	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	LP	LP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	HP

TABLE 25: Pearson Correlation Coefficient Matrix: Saturday 36 - 45 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	MP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	MP	LP	LN	HN	MN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	LN	MN	HP

TABLE 26: Pearson Correlation Coefficient Matrix: Saturday 46 - 55 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	--	MP	LP	LP	LP	LP	LP	MP	MP	HP				
PTI	--	MP	LP	--	--	--	LP	LP	LP	MP	HP			
TTI	LN	LN	MN	LN	LN	LN	MN	MN	MN	MN	MN	--		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	MP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	HN	HP

TABLE 27: Pearson Correlation Coefficient Matrix: Saturday 56 - 65 mph

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	--	MP	LP	--	--	--	LP	MP	MP	HP				
PTI	--	MP	LP	--	--	--	LP	LP	MP	MP	HP			
TTI	--	--	--	--	--	--	LN	LN	LN	MN	MN	LP		
TTV90	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	MP	MP	MN	HP

4.6 Correlation Matrices by ToD and Speed Limit

Data was segregated by speed limit category and ToD to conduct analysis and observe the relationships. Tables 28 to 31 show the Pearson correlation coefficient matrices for the four time periods with speed limit category <= 35mph. The correlation matrices by ToD for other speed categories were shown in Appendix.

The four matrices show that all the travel time performance measures are highly correlated with each other. The relationships between reliability measures varied between high, moderate and low correlations. Also, few reliability measures were found to be uncorrelated with other performance measures.

Table 28 shows the Pearson correlation coefficient matrix for Wednesday during 8am - 9am peak hour. It can be observed that the BTI, PTI, and TTI are not correlated with the maximum travel time and 95^{th} percentile travel time. In addition, the PTI was also found not correlated with TTV 90 and TTV 85. Table 29 shows the Pearson correlation coefficient matrix for Wednesday for 12pm - 1pm peak hour. In Table 29, all the performance measures were correlated with each other except PTI. The PTI was found to be not correlated with TTV 90 and TTV 85.

Table 30 shows the Pearson correlation coefficient matrix for Wednesday for 5pm - 6pm peak hour. In this case, the BTI, PTI, and TTI are not correlated with the maximum travel time. In addition, PTI was found not correlated with TTV 90 and TTV 85, while TTI was found not correlated with 85^{th}, 90^{th}, and 95^{th} percentile travel times.

Table 31 shows the Pearson correlation coefficient matrix for Wednesday for 9pm - 10pm off-peak hour. It was observed that BTI and PTI are not correlated with the maximum travel time. Also, BTI was found not correlated with 95^{th} percentile travel time

while PTI was found not correlated with TTV 85. Overall, TTV 85 was the common measure which was found not correlated in all the four time intervals. TTV 90 and maximum travel time were found not correlated except during 12pm – 1pm time interval.

TABLE 28: Pearson Correlation Coefficient Matrix: Wednesday <=35mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	MN	--	LN	MN	MN	MN	LN	LN	--	MP				
PTI	MN	--	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	MP	--	LP	MP	MP	LP	LP	LP	--	LN	MN	LN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	LP	--	MN	
TTV85	MP	HP	HP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	HP

TABLE 29: Pearson Correlation Coefficient Matrix: Wednesday <=35mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	HP	HP					
BTI	MN	LN	MN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	LN	LN	MN	MN	LN	LN	LN	LN	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN	LN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	LN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	HP

TABLE 30: Pearson Correlation Coefficient Matrix: Wednesday <=35mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	MN	--	LN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	--	LN	MN	MN	MN	LN	LN	LN	LP	HP			
TTI	MP	--	LP	MP	LP	LP	--	--	--	MN	MN	LN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	LP	--	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	LP	--	MN	HP

TABLE 31: Pearson Correlation Coefficient Matrix: Wednesday <=35mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	MP	MP	MP	MP	HP					
BTI	MN	--	LN	MN	MN	LN	LN	LN	--	MP				
PTI	LN	--	LN	LN	LN	LN	LN	LN	LP	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN			
TTV90	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	LP	LP	LN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	MP	LP	--	MN	HP

The Pearson correlation coefficient matrices based on ToD for Saturday, for speed limit category <=35mph, are shown in tables 32 to 35. The Pearson correlation coefficient matrices by ToD for other speed categories are shown in Appendix. Similar to the matrices during Wednesday, the travel time measures are highly correlated with each other while reliability measures have mixed relationships between the performance measures.

Table 32 shows the Pearson correlation coefficient matrix for Saturday for 8am – 9am peak hour. During 8am - 9am, it was observed that the BTI was not correlated with maximum travel time and 95th percentile travel time. The PTI was not correlated with the maximum travel time, 90th percentile travel time and TTV 85.

Table 33 shows the Pearson correlation coefficient matrix for Saturday for 12pm - 1pm peak hour. In this case, the BTI was found not correlated with TTV 85 while PTI was found not correlated with TTV 90 and TTV 85.

Table 34 shows the Pearson correlation coefficient matrix for Saturday for 5pm - 6pm peak hour. BTI, PTI, TTI were found not correlated with the maximum travel time and 95th percentile travel time. Also, BTI was found not correlated to TTV 85, PTI was found not correlated to TTI and TTV 90, and TTI was found not correlated to 85th and 90th percentile travel times.

Table 35 shows the Pearson correlation coefficient matrix for Saturday for 9pm - 10pm off-peak hour. BTI and TTI were found not correlated to the maximum travel time and 95th percentile travel time. In addition, PTI was found not correlated to TTI, TTV 90 and TTV 85.

Overall, the matrices show that the performance measures such as maximum travel time, 95th percentile travel time, TTV 85, BTI and PTI are common measures which were

found not correlated to other performance measures. The results clearly indicate that differences in relationships between reliability measures exist in most of the cases. However, the relationship between travel time measures remained constant in all the cases. The major variation while considering the ToD and speed limit combined was observed with the uncorrelated performance measures. When the different speed limit categories by ToD were compared, it was observed that the number of uncorrelated measures are different by, both, speed limit and ToD. Though, not much of variation was observed within the correlated measures, the variation within the uncorrelated measures indicate that there will be a variation in relationship between performance measures by ToD and speed limit category.

TABLE 32: Pearson Correlation Coefficient Matrix: Saturday <=35mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	MP	MP	MP	MP	HP					
BTI	MN	--	MN	MN	MN	MN	LN	LN	--	MP				
PTI	LN	--	LN	LN	LN	LN	LN	--	LP	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN	LN		
TTV90	LP	MP	MP	MP	MP	MP	MP	HP	HP	HP	MP	LP	LN	
TTV85	LP	MP	MP	MP	MP	MP	MP	MP	HP	HP	LP	--	MN	HP

TABLE 33: Pearson Correlation Coefficient Matrix: Saturday <=35mph 12pm -1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	HP					
BTI	MN	LN	MN	MN	MN	MN	MN	LN	LN	MP				
PTI	MN	LN	LN	MN	MN	MN	LN	LN	LN	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN	LN		
TTV90	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	LN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	--	--	MN	HP

TABLE 34: Pearson Correlation Coefficient Matrix: Saturday <=35mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	HP	MP	MP	MP	MP	MP	MP	HP					
BTI	MN	--	MN	MN	MN	MN	MN	LN	--	MP				
PTI	MN	--	MN	MN	MN	MN	MN	LN	--	MP	HP			
TTI	MP	--	LP	MP	MP	LP	--	--	--	LN	MN	--		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	--	LN	MN	HP

TABLE 35: Pearson Correlation Coefficient Matrix: Saturday <=35mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	LP	MP	MP	MP	HP					
BTI	MN	--	MN	MN	MN	MN	LN	LN	--	MP				
PTI	LN	--	LN	LN	LN	LN	LN	LN	--	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	LP	LP	LP	LN	MN	--		
TTV90	LP	MP	MP	MP	MP	MP	MP	HP	HP	HP	LP	--	LN	
TTV85	LP	MP	MP	MP	MP	MP	HP	HP	HP	HP	LP	--	MN	HP

4.7 Summary of Relationships Based on Year, DoW, ToD, WoY and Speed Limit

To study the overall variations due to factors like year, DoW, ToD, and WoY, a summary table was developed using data bars. To create the summary table of all the Pearson coefficient correlation matrices, values were initially assigned to each computed level of correlation. High correlations such as HP and HN were assigned a value of 3, moderate correlations such as MP and MN were assigned a value of 2, and low correlations such as LP and LN were assigned a value of 1. Zero was assigned if there is no correlation (blank cell in the previous tables).

After the values were assigned to all the matrices, the 17 matrices based on year, DoW, ToD, and WoY were summed up into single matrix (table). Table 36 shows the summary of all the matrices based on year, DoW, ToD, and WoY. The summary matrix has values ranging from 0 to 51. These values indicate that higher the value, higher is the correlation between two performance measures. Similarly, lower the value, lower is the correlation between the performance measures.

When any two measures are highly correlated with each other in all the matrices based on year, DoW, ToD and WoY, the maximum value will be (17 * 3) = 51. Similarly, if they are moderately correlated in the all the matrices, the maximum value will be (17 * 2) = 34. Likewise, if they are lowly correlated in all the matrices, the maximum value will be (17 * 1) = 17. Values between 51 to 34 or 34 to 17 or less than 17 indicate that the performance measures showed variations in their relationships or are uncorrelated in at least one of the 17 matrices.

From Table 36, it can be observed that most of the travel time measures were found to have higher values. This indicates that they are highly correlated to each other. Whereas,

the reliability measures such as BTI, PTI, and TTI were found to have lower values, indicating that they are lowly correlated with travel time measures.

A summary table based on speed limit was also developed to study the overall variations by speed limit. Similar to Table 36, high correlations such as HP and HN were assigned a value of 3, moderate correlations such as MP and MN were assigned a value of 2, and low correlations such as LP and LN were assigned a value of 1. The eight speed limit based matrices were added to create a summary matrix. The summary matrix with values can be seen in Table 37. The summary matrix has values from 0 to 24. These values indicate that higher the value, higher is the correlation between two performance measures. Similarly, lower the value lower is the correlation between the performance measures.

When any two measures are highly correlated with each other in all the matrices based on speed limit, the maximum value will be (8 * 3) = 24. Similarly, if they are moderately correlated in all the matrices, the maximum value will be (8 * 2) = 16. Likewise, if they are lowly correlated in the all the matrices, the maximum value will be (8 * 1) = 8. Values between 24 to 16 or 16 to 8 or less than 8 indicate that the performance measures showed variations in their relationships or are uncorrelated in at least one of the eight matrices.

From Table 37, it can be observed that most of the travel time measures were found to have higher values, indicating that they are highly correlated to each other. However, the reliability measures such as BTI, PTI, and TTI were found to have lower values, indicating that they are lowly correlated with travel time measures.

BT is correlated with all reliability measures in tables 36 and 37.

TABLE 36: Summary Matrix Based on Year, DoW, ToD, WoY

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	40													
ATT	51	51												
TT10	51	46	51											
TT15	51	46	51	51										
TT50	51	49	51	51	51									
TT85	51	51	51	51	51	51								
TT90	51	51	51	51	51	51	51							
TT95	51	51	51	51	51	51	51	51						
BT	31	39	34	33	33	34	37	38	42					
BTI	23	11	17	18	18	17	14	14	15	34				
PTI	17	14	17	17	17	17	17	16	9	32	51			
TTI	21	13	16	19	18	16	15	11	13	31	48	33		
TTV90	33	41	34	34	34	34	40	42	45	51	33	20	32	
TTV85	33	38	34	34	34	34	40	41	43	51	28	20	33	51

TABLE 37: Summary Matrix Based on Speed Limit

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	16													
ATT	24	23												
TT10	24	19	24											
TT15	24	19	24	24										
TT50	24	22	24	24	24									
TT85	23	23	24	24	24	24								
TT90	23	24	24	23	24	24	24							
TT95	22	24	24	23	24	24	24	24						
BT	14	21	19	16	16	16	20	21	23					
BTI	8	10	12	10	10	11	11	13	13	18				
PTI	8	9	10	8	8	7	9	9	9	13	24			
TTI	10	8	12	11	11	9	12	12	10	14	19	10		
TTV90	16	21	20	16	16	19	21	23	23	24	13	8	16	
TTV85	15	20	20	16	16	19	22	23	23	24	12	7	17	24

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Congestion and delays in the transportation network is almost inevitable and happens on a time to time and day to day basis. Road users are often interested in the expected travel time whenever they are planning a trip. It is important that road users reach their destination within the expected travel time, without any additional delays. Hence, reliability of the road network is an important for road users.

This study was conducted to categorize data, explore, and identify factors that influence the relationships between travel time based performance measures. The Pearson correlation coefficient analysis performed between travel time measures and reliability measures was conducted by year, DoW, ToD, WoY, and speed limit category. The results from the Pearson correlation coefficient matrices indicate that all the travel time measures are generally correlated with each other. However, the reliability measures are not correlated in most of the analytical scenarios. All the travel time measures were positively correlated with each other in all the matrices. Whereas the reliability measures show a mix of both positive and negative correlations with each other. Also, the reliability measures like BT, TTV85 and TTV90 are positively correlated while BTI. PTI and TTI are negatively correlated with travel time measures in most of the matrices except for few instances.

The BTI, PTI, TTI, and travel time variations based on 90th and 85th percentile travel times were observed to be not correlated with travel time measures in most of the analytical scenarios explored in this study.

When DoW was considered, it was observed that there is a moderate effect on the relationship between travel time based performance measures. ToD is an important factor which resulted in major variations in relationships between travel time based performance measures. However, WoY did not have much effect on the relationships between travel time based performance measures. The speed limit is important factor and was found to influence the relationship between travel time based performance measures. Further, when the combined effect of speed limit and ToD was considered, it was found to have a major effect on the relationship between the travel time based performance measures.

The results from the Pearson correlation coefficient evaluation indicate that the average travel time was the only travel time measure which was correlated with all the travel time based performance measures. BT was the only reliability measure which was observed to be correlated with all the travel time based performance measures. The performance of a link can be identified using the average travel time. The average travel time also provides information about the link congestion. Along with the average travel time, other travel time measures such as 10th, 15th, 50th, 85th, 90th, and 95th percentile travel times can be used in before and after studies. However, travel time measures cannot be used to compare the performance of any two links.

The travel time variations such as TTV85 and TTV 90 can be used for before and after studies and to compare the performance of two links with similar characteristics. BT which depends on the average travel time and PT which depends on the 95th percentile

travel time can be used for before and after studies. On the other hand, both BT and PT cannot be used for comparing the performance of any two links.

The BTI was found not correlated with a few travel time measures but was found to be correlated with the all the reliability measures. Hence, BTI can be used to compare the reliability of any two links in a network and provides information regarding delay and reliability of a link. Therefore, BTI was the best reliability measure to evaluate the network performance. Also, the PTI and TTI can also be used to evaluate the condition of facility, and to compare any two links in the transportation network. However, their relationship with other reliability measures is not consistent.

Overall, the Pearson correlation coefficients computed show that the relationships between travel time performance measures vary by year and depend on DoW, ToD, and speed limit categories. The differences in relationships were more consistent for average travel time, BT, and BTI even if these factors were considered. Therefore, these three performance measures are recommended to transportation project / alternative evaluations and assessments.

5.1 Effect of Sample Size

In this research, the sample size used for different datasets are different. Sample size definitely has an effect on the outcomes from any research. It is recommended that the sample size should not be too small. At the same time, a large sample size can create a lot of noise and scatter due to the influence other exogenous variables (characteristics that vary from one link to another link in the transportation network). Clustering data based on such

influential exogenous variables and examining the relationships might yield more meaningful and accurate results related to the relationships.

5.2 Future Scope

In this research, only correlations were developed to study the relationships between the travel time based performance measures. Neural network models and statistical models can be developed to study the influence of various network characteristics like the shoulder width, the number of lanes, and the speed limit on travel time based performance measures. Also, only linear distribution was examined by computing Pearson correlation coefficients in this research. The possibility of non-linear distributions to better explain the relationships merits an investigation.

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APPENDIX: PEARSON CORRELATION MATRICES

TABLE 1: Pearson Correlation Coefficient Matrix: Wednesday 36-45mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	MN	--	LN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	--	MN	MN	MN	MN	LN	LN	LN	LP	HP			
TTI	MP	LN	LP	MP	MP	LP	LP	--	--	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	HP

TABLE 2: Pearson Correlation Coefficient Matrix: Wednesday 36-45mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	LP	LP	LN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	MP	MP	HP	HP	LP	LP	LN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	HP	HP	LP	--	MN	HP

TABLE 3: Pearson Correlation Coefficient Matrix: Wednesday 36-45mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	HP	HP	HP					
BTI	MN	LP	LN	MN	MN	MN	LN	LN	LN	MP				
PTI	MN	LP	LN	MN	MN	MN	LN	LN	LN	LP	HP			
TTI	MP	LN	LP	MP	MP	LP	LP	LP	--	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	
TTV85	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	LP	LP	MN	HP

TABLE 4: Pearson Correlation Coefficient Matrix:
Wednesday 36-45mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	LP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	MP	MP	LN	MN	MN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	LN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	--	LN	LN	HP

TABLE 5: Pearson Correlation Coefficient Matrix:
Saturday 36-45mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	LP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	MP	MP	LN	MN	MN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	--	--	LN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	--	LN	LN	HP

TABLE 6: Pearson Correlation Coefficient Matrix:
Saturday 36-45mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	MP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	LP	LP	LN	MN	MN		
TTV90	MP	HP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	HP

TABLE 7: Pearson Correlation Coefficient Matrix
Saturday 36-45mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	LP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	LP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	MP	MP	LN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	LN	
TTV85	MP	HP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	HP

TABLE 8: Pearson Correlation Coefficient Matrix:
Saturday 36-45mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	LP	LP	MP	MP	MP					
BTI	MN	LN	MN	MN	MN	MN	MN	MN	MN	MP				
PTI	MN	LN	MN	MN	MN	MN	MN	MN	LN	MP	HP			
TTI	MP	LP	MP	MP	MP	MP	MP	MP	MP	LN	HN	MN		
TTV90	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	
TTV85	MP	MP	MP	MP	MP	MP	MP	MP	MP	HP	LP	--	MN	HP

TABLE 9: Pearson Correlation Coefficient Matrix:
Wednesday 46-55mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	MP	HP	HP	HP	HP	HP	HP							
TT95	MP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	HP	HP	HP	HP					
BTI	--	MP	MP	LP	LP	LP	MP	MP	MP	MP				
PTI	--	MP	LP	--	--	LP	LP	LP	LP	MP	HP			
TTI	LN	MN	MN	LN	LN	MN	MN	MN	MN	MN	HN	MN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 10: Pearson Correlation Coefficient Matrix:
Wednesday 46-55mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	HP	HP	HP	HP					
BTI	LP	MP	MP	LP	LP	LP	MP	MP	MP	HP				
PTI	LP	MP	LP	LP	LP	LP	LP	LP	MP	MP	HP			
TTI	LN	MN	MN	LN	LN	MN	MN	MN	MN	MN	HN	MN		
TTV90	MP	HP	HP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MN	
TTV85	MP	HP	HP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MN	HP

TABLE 11: Pearson Correlation Coefficient Matrix:
Wednesday 46-55mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	LN	MP	--	LN	LN	--	LP	LP	MP	MP				
PTI	LN	MP	--	LN	LN	LN	--	--	LP	MP	HP			
TTI	--	MN	LN	--	--	LN	MN	MN	MN	MN	MN	LN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	--	MN	HP

TABLE 12: Pearson Correlation Coefficient Matrix:
Wednesday 46-55mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	MP	MP	MP	MP	MP	HP	HP					
BTI	LP	MP	MP	LP	LP	LP	MP	MP	MP	HP				
PTI	--	MP	LP	LP	LP	LP	MP	MP	MP	HP	HP			
TTI	LN	LN	LN	LN	LN	LN	MN	MN	MN	MN	HN	MN		
TTV90	MP	HP	MP	MP	MP	MP	HP	HP	HP	HP	HP	HP	MN	
TTV85	MP	HP	HP	MP	MP	MP	HP	HP	HP	HP	HP	MP	MN	HP

TABLE 13: Pearson Correlation Coefficient Matrix:
Saturday 46-55mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	HP	HP	HP	HP					
BTI	--	MP	LP	--	--	--	LP	LP	MP	MP				
PTI	--	MP	LP	--	--	LP	LP	LP	MP	MP	HP			
TTI	--	MN	LN	--	--	--	LN	LN	MN	MN	HN	MN		
TTV90	MP	HP	HP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MN	
TTV85	MP	HP	HP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MN	HP

TABLE 14: Pearson Correlation Coefficient Matrix:
Saturday 46-55mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	HP	MP	MP	HP	HP	HP	HP					
BTI	--	MP	LP	LP	LP	LP	MP	MP	MP	HP				
PTI	--	MP	LP	LP	LP	LP	MP	MP	MP	MP	HP			
TTI	--	LN	MN	LN	LN	LN	MN	MN	MN	HN	HN	MN		
TTV90	MP	MP	HP	MP	MP	HP	HP	HP	HP	HP	MP	MP	HN	
TTV85	MP	MP	HP	MP	MP	HP	HP	HP	HP	HP	MP	MP	HN	HP

TABLE 15: Pearson Correlation Coefficient Matrix:
Saturday 46-55mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	MP	HP	HP	HP					
BTI	--	MP	LP	--	--	--	LP	LP	MP	HP				
PTI	--	LP	--	--	--	--	--	--	LP	MP	HP			
TTI	LN	LN	MN	LN	LN	LN	MN	MN	MN	MN	MN	LP		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	--	MN	
TTV85	MP	MP	HP	MP	MP	MP	HP	HP	HP	HP	MP	--	HN	HP

TABLE 16: Pearson Correlation Coefficient Matrix:
Saturday 46-55mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	MP	HP	HP	HP	HP	HP							
TT95	HP	MP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	HP	HP	HP					
BTI	--	LP	LP	--	--	--	LP	LP	MP	HP				
PTI	--	MP	LP	--	--	LP	LP	MP	MP	HP	HP			
TTI	--	--	--	--	--	--	LN	LN	LN	MN	HN	MN		
TTV90	MP	MP	HP	MP	MP	HP	HP	HP	HP	HP	MP	MP	MN	
TTV85	MP	MP	HP	MP	MP	MP	HP	HP	HP	HP	HP	MP	MN	HP

TABLE 17: Pearson Correlation Coefficient Matrix:
Wednesday 56-65mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	MP	HP	HP	MP	HP	HP								
TT90	MP	HP	HP	MP	HP	HP	HP							
TT95	MP	HP	HP	MP	MP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	HP	HP	HP	HP					
BTI	--	MP	LP	--	--	LP	MP	MP	MP	MP				
PTI	--	MP	LP	--	--	--	LP	LP	LP	MP	HP			
TTI	--	MN	MN	LN	LN	MN	MN	MN	MN	MN	MN	LN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 18: Pearson Correlation Coefficient Matrix:
Wednesday 56-65mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	MP	HP	HP	HP	HP	HP							
TT95	HP	MP	HP	HP	HP	HP	HP	HP						
BT	LP	MP	MP	LP	LP	LP	LP	MP	HP					
BTI	--	MP	LP	LP	LP	--	LP	LP	MP	HP				
PTI	LP	MP	LP	LP	LP	LP	LP	LP	MP	HP	HP			
TTI	LP	MP	LP	LP	LP	LP	LP	LP	MP	MP	MP	HP		
TTV90	MP	MP	MP	MP	MP	MP	MP	HP	HP	MP	MP	MP	MP	
TTV85	HP	MP	HP	HP	HP	HP	HP	HP	HP	MP	LP	LP	LP	HP

TABLE 19: Pearson Correlation Coefficient Matrix:
Wednesday 56-65mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	HP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	MP	HP	HP	HP	HP	HP								
TT90	MP	HP	HP	HP	HP	HP	HP							
TT95	MP	HP	HP	MP	HP	HP	HP	HP						
BT	MP	HP	HP	MP	MP	HP	HP	HP	HP					
BTI	--	MP	MP	--	LP	LP	MP	MP	MP	MP				
PTI	--	MP	LP	--	--	--	LP	LP	MP	MP	HP			
TTI	--	MN	MN	LN	LN	MN	MN	MN	MN	MN	HN	MN		
TTV90	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	
TTV85	MP	HP	HP	MP	MP	HP	HP	HP	HP	HP	MP	LP	MN	HP

TABLE 20: Pearson Correlation Coefficient Matrix:
Wednesday 56-65mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	MP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	MP	MP					
BTI	--	LP	--	--	--	--	--	LP	LP	HP				
PTI	--	LP	--	--	--	--	--	LP	MP	HP	HP			
TTI	LP	MP	LP	LP	LP	LP	LP	LP	LP	MP	MP	MP		
TTV90	MP	MP	HP	MP	MP	MP	HP	HP	HP	HP	MP	MP	LP	
TTV85	HP	HP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MP	LP	HP

TABLE 21: Pearson Correlation Coefficient Matrix:
Saturday 56-65mph 8am-9am

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	HP													
ATT	HP	HP												
TT10	HP	HP	HP											
TT15	HP	HP	HP	HP										
TT50	HP	HP	HP	HP	HP									
TT85	HP	HP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	HP	MP	HP	HP	HP	HP	HP	HP	HP					
BTI	--	LN	--	--	--	--	--	--	--	LP				
PTI	--	LP	--	--	--	--	--	--	--	LP	MP			
TTI	LP	MP	LP	LP	LP	LP	LP	LP	LP	--	MN	LP		
TTV90	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	--	LP	--	
TTV85	HP	MP	HP	HP	HP	HP	HP	HP	HP	HP	--	--	--	HP

TABLE 22: Pearson Correlation Coefficient Matrix:
Saturday 56-65mph 12pm-1pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	HP	HP					
BTI	--	MP	LP	--	--	--	LP	MP	MP	HP				
PTI	--	MP	LP	--	--	--	LP	MP	MP	HP	HP			
TTI	--	--	--	--	--	--	LN	LN	LN	MN	LN	--		
TTV90	MP	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	MP	MN	HP

TABLE 23: Pearson Correlation Coefficient Matrix:
Saturday 56-65mph 5pm-6pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	HP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	MP	MP	MP	MP	MP	MP	MP	HP	HP					
BTI	--	MP	LP	--	--	--	LP	MP	MP	HP				
PTI	--	MP	LP	--	--	--	LP	MP	MP	MP	HP			
TTI	--	--	--	--	--	--	LN	LN	MN	MN	MN	LP		
TTV90	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	HP	MP	MN	
TTV85	MP	MP	MP	MP	MP	MP	HP	HP	HP	HP	MP	MP	MN	HP

TABLE 24: Pearson Correlation Coefficient Matrix:
Saturday 56-65mph 9pm-10pm

Measures	MinTT	MaxTT	ATT	TT10	TT15	TT50	TT85	TT90	TT95	BT	BTI	PTI	TTI	TTV90
MaxTT	MP													
ATT	HP	MP												
TT10	HP	MP	HP											
TT15	HP	MP	HP	HP										
TT50	HP	MP	HP	HP	HP									
TT85	HP	MP	HP	HP	HP	HP								
TT90	HP	MP	HP	HP	HP	HP	HP							
TT95	HP	HP	HP	HP	HP	HP	HP	HP						
BT	LP	HP	LP	LP	LP	LP	LP	LP	HP					
BTI	--	MP	LP	--	--	--	--	--	MP	HP				
PTI	--	MP	LP	--	--	--	--	--	MP	HP	HP			
TTI	--	MP	LP	--	--	--	--	--	MP	HP	HP	HP		
TTV90	HP	MP	HP	HP	HP	HP	HP	HP	HP	MP	MP	MP	LP	
TTV85	HP	MP	HP	HP	HP	HP	HP	HP	HP	MP	LP	LP	LP	HP