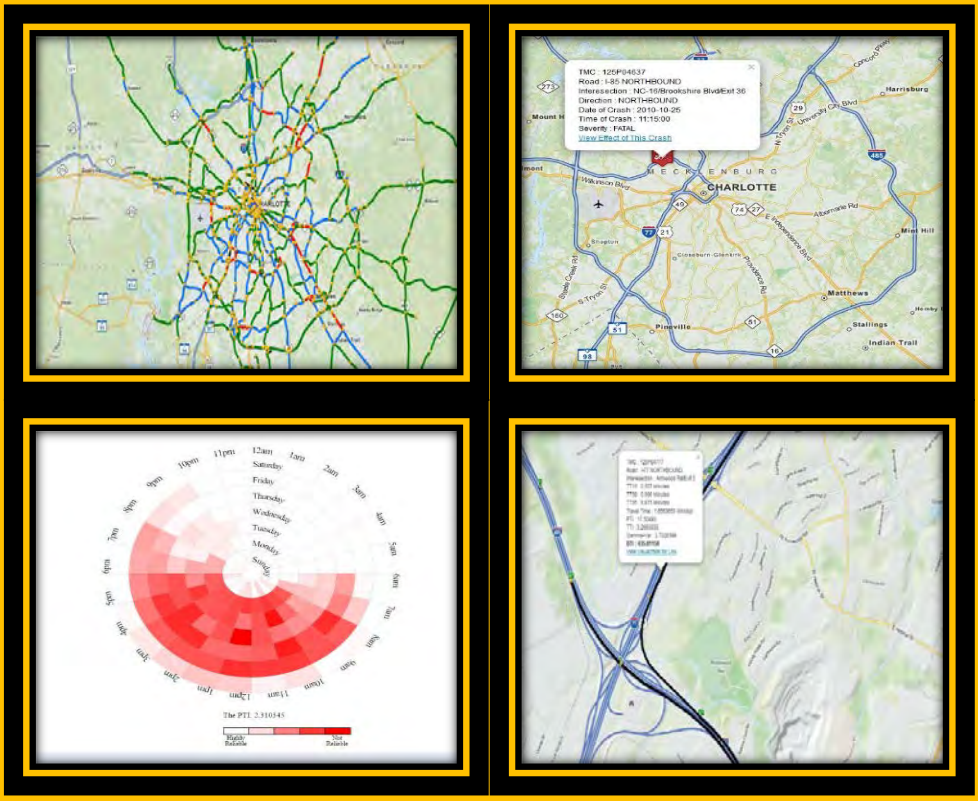
COMMERCIAL REMOTE SENSING & SPATIAL INFORMATION (CRS & SI) TECHNOLOGIES PROGRAM FOR RELIABLE TRANSPORTATION SYSTEMS PLANNING: VOLUME 1 - COMPARATIVE EVALUATION OF LINK-LEVEL TRAVEL TIME FROM DIFFERENT TECHNOLOGIES AND SOURCES



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16. Abstract

Accurate travel time information is required to efficiently plan and effectively manage transportation network. Technologies and private data sources such as INRIX, TomTom and HERE offer the potential to continuously collect travel time data and use it for long-term transportation planning as well as real-time traffic condition monitoring. However, their ability to accurately collect travel time data is still unclear. The first phase of this study focused on capturing and estimating link/section level travel times on arterial streets and freeways using manual floating car method, Global Positioning System (GPS) floating car method, Bluetooth detectors, and INRIX. A comparison between travel times collected manually and using various technologies / sources (GPS, Bluetooth detectors and INRIX) was performed for each travel time run. Results showed that both Bluetooth detectors and INRIX yield promising estimates for freeways. However, travel time data captured for arterial streets using Bluetooth detectors are less accurate and not dependable when compared to other technologies. Moreover, data from Bluetooth detectors captured using the vendor's software showed a significant number of outliers. Therefore, the second phase focused on filtering raw sample of Bluetooth detectors data, estimating travel time, and then comparing with manual travel time data to recommend filtering and data capturing criteria. The effect of spacing between the Bluetooth detectors and signal cabinet controller location (in which Bluetooth detector was placed) on the percent difference in travel time was examined. The role of on-network and temporal characteristics on difference in travel time from GPS, Bluetooth detectors and INRIX (when compared to ground truth) was also examined.

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EXECUTIVE SUMMARY

Accurate travel time information is required to efficiently plan and effectively manage transportation network. Technologies and private data sources such as INRIX, TomTom and HERE offer the potential to continuously collect travel time data and use it for long-term transportation planning as well as real-time traffic condition monitoring. However, their ability to accurately collect travel time data is still unclear and merits investigation. Six study corridors comprised of five arterial streets and one interstate freeway corridor in the city of Charlotte, North Carolina were selected to capture travel time information and to compare the travel times from various data sources such as manual floating car method, Global Positioning Systems (GPS) floating car method, Bluetooth detectors (installed in the signal cabinet controllers on arterial streets and traffic monitoring camera boxes on freeway) and INRIX.

The travel time data was collected for two days along each corridor. Travel times for different time periods were captured, for selected sections along each corridor, to evaluate the effectiveness of the methods and technologies in collecting data by time period. Manual and GPS floating car based data were collected from 7 AM - 9 AM, 11 AM - 1 PM, and 4 PM - 6 PM on day 1 and 7 AM - 10 AM and 3 PM - 6 PM on day 2. The data collected using Bluetooth detectors and INRIX was also for the same selected sections along each study corridor for both the data collection days. With Charlotte Uptown as center, the direction of travel was identified as either inbound (towards uptown) or outbound (away from uptown).

The quality and accuracy of travel times obtained from GPS unit, Bluetooth detectors, and INRIX was evaluated by comparing it with manual data (ground truth) for each travel time run. In addition to descriptive analysis, t-tests were conducted at a 95% confidence level.

Travel time data collected using GPS units are almost equivalent to the data collected manually for both arterial streets and freeways. The travel times from INRIX are more promising when compared to the travel times from the Bluetooth detectors based on Acyclica filtering technique. The Bluetooth detectors showed more samples in higher percentage difference range (for most time periods considered) than INRIX.

Based on the start and end times of each travel time run, filter ranges of ±1.5 min, ± 2.5 min and ± 5 min are proposed and tested to perform micro-level analysis of the raw sample from Bluetooth detectors to look at differences in travel times. The travel times, based on detections at section-level, lower than minimum travel time (based on travel speed = 20 mph) and maximum travel time (based on travel speed = speed limit + 10 mph) were excluded from analysis and evaluation in this case. Out of the three filter ranges, ±1.5 min filter range yielded accurate results but fewer numbers of detections. As expected, the number of detections increased with an increase in the filter range.

The travel times from INRIX were observed to be more promising than those obtained from Bluetooth detectors even after incorporating the proposed filtering technique. When compared individually for arterial streets and freeways, the travel time data from both Bluetooth detectors and INRIX are reasonably close to manually captured section travel time data along the considered freeway (I-85) corridor than when compared to the parallel arterial street (North Tryon St) corridor. Even for other arterial streets, travel times from INRIX are relatively more promising when compared to the travel times from the Bluetooth detectors (even when the proposed filtering technique was adopted to remove outliers and better detections, hence, sample size). Overall, the Bluetooth detectors showed more samples in higher percentage difference (for most time periods considered) than INRIX even after filtering the data.

The relationship between spacing of Bluetooth detector locations at which data are captured indicate that, as the spacing between the Bluetooth detectors increased, the percentage difference in travel time decreased along with the increase in total number of detections. The placement location of Bluetooth detector and ability to capture data in both directions does not seem to have an effect on travel time estimation (accuracy).

Overall, INRIX was found to be a better data source to extract travel time on arterial streets than when compared to Bluetooth detectors at the time of this study. The reasons for the difference in travel time obtained using Bluetooth detectors and INRIX could be the source of data, outliers, and on-network characteristics.

The number of samples detected (detection rate) using Bluetooth detectors seem to vary based on the time-of-the-day. It was observed that detection rate is relatively very low during morning peak hours. This could be partly attributed to relatively higher traffic volumes during afternoon and evening peak hours in the study area, while environmental conditions could be another associated factor. The placement location of Bluetooth detectors (whether the signal cabinet controller is along the inbound or outbound side at the intersection) does not seem to have an effect on detection rate or penetration rate by time-of-the-day. Increased usage of Bluetooth enabled devices and technological advancements may lead to improved capture of detections and data quality using Bluetooth detectors in the future.

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CHAPTER 1: INTRODUCTION

Traffic demand has been progressively increasing with the development of modern civilization and need for more travel. The subsequent effect of this increasing travel demand is overcrowding of the limited road network. Addressing congestion has been one of the primary objectives of transportation system managers, planners, and engineers. The Federal Highway Administration (FHWA) recommends using the travel time experienced by motorists on our road system to quantify the effects of congestion (AASHTO, 2008). Travel time and congestion are also useful measures for motorists or system users to make route choice, mode choice or departure time decisions.

Travel time is a fundamental measure used in many fields associated to transportation. It is a simple concept understood and communicated by a wide range of audiences, including transportation engineers and planners, business persons, commuters, media representatives, administrators, and consumers (TTI, 1998). The measure can also be easily understood by non-technical persons (example, politicians, advocacy groups, and the general public) who are involved in decision making process related to transportation planning, policy and system usage. Also, some transportation related analyses compare various transportation modes for / from a common funding source using travel time as the element.

Effective monitoring of traffic performance is very important for transportation agencies. It assists in short-range and long-range transportation planning decisions. In addition, real-time performance measurement provides travelers and transportation agencies with accurate travel time data that are used to make decisions on their current trips, especially for roadways which experience high variability in traffic flow.

Travel time studies are important from transportation planning perspective as it depicts the level of congestion on a particular link. Travel time is also used by transportation planners in regional travel demand forecasting models and when performing traffic impact studies. A comprehensive database with real time travel information is also collected and disseminated by transit authority management and freight logistics for marketing analysis, patronage forecasting, and efficient on-time goods delivery. Further, travel time is a measure of quality-of-service (QOS) or level-of-service (LOS) to motorists and passengers, and also an indicator of relative congestion along the section of roadways. Many travel demand forecasting models, therefore, require good and accurate travel time measures (Roess, 2011).

The most conventional means of collecting travel time data is using a floating test car method. However, the sample size from this approach would be very limited. It is also a tedious, expensive, and time-consuming data collection process. Travel time data were also captured using on-road traffic sensors, loop detectors, automatic license plate recognition (ALPR) systems, Radio Frequency Identification (RFID) tag reader systems, and video surveillance cameras in the past (Haghani et al., 2010; Vo, 2011). A few other technological means of collecting travel time data include cell phone tracking, Global Positioning Systems (GPS) equipped probe vehicles, and transit buses with GPS or automatic vehicle location (AVL) units as probe vehicles (Kim et al., 2011). These devices or methods are used by transportation agencies along with the participation of motorists for effective transportation planning, safety analysis, resource allocation, and security surveillance.

Besides the aforementioned technologies, Bluetooth detectors are an alternative and inexpensive means of accurately measuring travel time (Vo, 2011). Bluetooth detectors compute the travel time based on Media Access Control (MAC) addresses of Bluetooth enabled devices in

vehicles. Recently, INRIX, TomTom, HERE, etc. have emerged as private vendors of data pertaining to travel time and average speed. As an example, INRIX provides accurate real-time, historical, predictive traffic services, and incident data on freeways, highways, and secondary roadways, including arterial streets and side streets of North America and Europe (INRIX, 2014). The sources of data from private vendors are mapping application users / mobile devices, GPS equipped vehicles, and traditional road sensors. The archived traffic data is being used by several agencies to facilitate traffic management, traveler information, and planning activities for both local and long distance travelers.

1.1. Need for Research

Typical performance measures used by practitioners and system users include travel time and travel speed. The accuracy and validity of predicting transportation system reliability also depends on travel time data. While GPS has been used widely in the past, there is an increase in the use of Bluetooth detectors and cell phone tracking devices in recent years. Collecting congestion related or travel time data over time with GPS in test vehicles or Bluetooth detectors along corridors for the entire transportation network is a time consuming and expensive task. At the same time, collecting data from GPS test vehicles does not account for diversity and stochasticity, therefore, leading to inaccurate estimates. Incorporating the influence of different vehicle types (make, model, and operating characteristics) and behaviors of motorists (by age, gender, etc.) is also difficult using this method. Further, using test-car method or GPS-based data also pose unprecedented issues different from other sciences and technologies including issues of privacy and security (Hitchings, 2003).

At present, ample opportunities exist in the form of data from Closed Circuit Television (CCTV) cameras, sensors or loop detectors in the pavement, Bluetooth detectors with robust applications, as well as GPS units installed to track buses and commercial vehicles (non-connected devices that do not interrupt the flow of traffic while capturing information). While the use of travel time data from non-connected devices such as Bluetooth detectors and INRIX has rapidly increased in recent years, their applicability to accurately collect travel time on all types of facilities is still unclear and merits investigation.

Literature documents research on validating travel times obtained from various sources such as GPS, Bluetooth detectors, and INRIX. Almost all the studies are based on corridor level analysis. These studies considered average travel time by aggregating travel times collected for several sections along the corridor. The characteristics of a corridor may vary from one link to another link. The travel time could also vary based on time-of-the-day and direction of travel. There is a need to collect and compare travel time data for each run, for each section, to accurately identify the best technology or source of travel time data.

Literature documents limited efforts comparing GPS, Bluetooth detectors and INRIX for arterial streets (when compared to freeways). Factors such as signals detected from pedestrians, bicyclists, nearby shops, restaurants etc. could skew the travel time estimates from Bluetooth detectors on arterial streets. The spacing between Bluetooth detectors and their placement location could have an effect on travel time estimates. Incorporating an appropriate filtering technique may yield better results from Bluetooth detectors. There is a need to research and develop a suitable filtering technique to identify and remove outliers resulting from such sources in case of arterial streets.

1.2. Research Objectives

The key objectives of this research, therefore, are:

1. to collect and evaluate the accuracy of estimated micro-level travel time data from manual procedure, GPS equipped vehicle, Bluetooth detectors, and INRIX for both freeway and arterial streets,
2. to research and compare the ability to capture temporal variations in travel times from the selected sources of travel time data,
3. to develop new methods to filter data obtained from Bluetooth detectors for accurate travel time estimation,
4. to examine the correlation between travel times collected manually and using various technologies (GPS, Bluetooth and INRIX),
5. to examine the correlation between travel times and on-network characteristics such as the number of lanes, speed limit, traffic volumes, number of signalized and unsignalized intersections, and,
6. to recommend the best technology or the best combination of technologies to capture travel time.

1.3. Organization of the Research Report

The remainder of this report is comprised of four chapters. A review of existing literature on travel time studies and different technologies and sources used in the past are discussed in Chapter 2. The methodology and data collection procedure is discussed in Chapter 3. Comparison and evaluation of travel times from various technologies and sources are presented in Chapter 4. Conclusions from this study are presented in Chapter 5.

CHAPTER 2: LITERATURE REVIEW

The widespread use of digital technologies, combined with rapid sensor advancements resulted in a paradigm shift in geospatial technologies around the end of last millennium (Greiner-Brzezinska et al., 2004). Airborne imagery has been the main source of geospatial information, and the information extraction process included flight planning, establishing ground control for image geo-referencing, acquisition of photography, film development, operator based photo evaluation and three-dimensional (3D) data extraction on analog opto-mechanical, analytical opto-mechanical-electronic, and, fully digital visualization and measurement instruments (Paska, 2009).

Digital images from satellites, aerial platforms and unmanned aerial vehicles (UAVs) are primarily used for surveillance. These photographically- or stereoscopically-derived data have better horizontal accuracy but weaker vertical accuracy. Terrain data, on the other hand, are better captured using optical and laser sensors (includes **Li**ght **D**etection **A**nd **R**anging [LiDAR]).

The use and application of commercial remote sensing technologies to measure or forecast traffic congestion and operational performance, however, though has been very limited. Traffic congestion and operational performance varies dynamically over time and space. Data need to be collected more frequently over space under different network conditions to capture day-to-day as well as within-a-day variations for better estimation of transportation system reliability (spatially and temporally).

Airborne imagery may not be best applicable to capture temporal variations in traffic congestion and transportation network performance (say, travel time). Transportation planners, engineers and researchers heavily rely on "spatial information technologies" that include GPS, Geographic Information Systems (GIS) and related Intelligent Transportation Systems (ITS) and services to collect or gather data, by time-of-the-day and day-of-the-week, to compute travel time and assess reliability of transportation systems.

Computing accurate travel time and reliability of all the links in the network will help in building and maintaining well calibrated regional travel demand forecasting models and, hence, project selection. Mapping temporal and spatial variations in traffic congestion will not only help understand the spatial relationship between factors (effect of socio-economic, demographic, land use and network characteristics) that lead to congestion but will also assist in identifying suitable congestion mitigation strategies and prioritization of limited available funds. Integrating travel time data spatially with crash data will assist in quantifying congestion and reliability of our roads as well as in understanding the effect (on severity, duration and extent of congestion) of crashes on travel delays. Capturing and mapping travel time information in real-time or near-real time will lead to provision of accurate route-guidance information, and assist in selection of mode and departure time for traveling public (through dissemination; pre-trip planning and near real-time route guidance). It will also help in provision of improved emergency response and timely delivery of goods and services. Accurate temporal and spatial variations in travel time information and reliability are, therefore, vital for both long range and short-term transportation planning.

A review of past research on the use of GPS, Bluetooth detectors, and INRIX for travel time studies is conducted and presented next. It is divided into three sections: 1) GPS for travel time studies, 2) Bluetooth detectors for travel time studies, and, 3) INRIX for travel time studies.

2.1. GPS for Travel Time Studies

GPS is a satellite-based positioning system that provides precise temporal and spatial information on individual receivers or relative positions between co-observing receivers (Hong and Vonderohe, 2011). The Department of Defense monitors and maintains GPS closely and can disable the system anytime (TTI, 1998). Quiroga and Bullock (1999) conducted a study on arterial streets to obtain travel time using GPS and dynamic sequestration technique. They used a general data model that includes a spatial model, a geographic location database, and GPS data transfer procedure using dynamic segmentation tools. Their study concluded that the accuracy in measuring travel time and speed using this technique improves more than those using traditional techniques.

Positional error in GPS is largely influenced by factors such as satellite and receiver clock biases, atmospheric refraction, satellite ephemeris inexactness, multi-pathing, satellite geometry, and human bias (Hong and Vonderohe, 2011). GPS accuracy varies depending on positioning methods. The sampling rate is identified as another error source for transportation data collected from the vehicles. Given a constant vehicle speed, latency between successive GPS points is proportional to sampling rates. Decreasing sampling rate increases spatial uncertainties between GPS points and roadway maps and subsequently affects route measures between successive GPS points along roadways.

According to a study by Mauricio et al. (2003) on collecting and utilizing travel time data through GPS and GIS on arterial streets in Philippines, the GPS units should be exposed to at least three satellites for tracing the location. The duration can range from 5 minutes to 30 minutes depending on the GPS unit position regarding the satellite. The day of survey, time of survey, and route information should be recorded while performing the run. Less staff requirements, less human error, detailed data collection opportunity, good accuracy, and automatic geo-coding procedures are some of the many benefits of using GPS based system for travel time data collection. Signal loss, retrieving the base map, necessary and updated equipment identification, limited sample, and high cost per unit of data are some of the drawbacks of that system (TTI, 1998; Koprowski, 2012).

2.1.1. Feasibility and Applicability of Using GPS

Bel-O-Mar Regional Council (2007) conducted a travel time study using GPS on US-250 and SR-331 in Belmont County and portions of US-250 and WV-2 in Ohio and Marshall Counties in West Virginia. They used the floating car technique (a vehicle mounted with a GPS antenna) to obtain average travel time and speed. The GPS data logger recorded the coordinates of the position every two seconds. They concluded that GPS can be used as an efficient and in an advantageous way to collect travel time data.

Wilbur Smith Associates (2007) used GPS units to record the spatial coordinates and time of the test vehicle at every 0.03 mile (158 feet) for analyzing travel time and delay on major local and arterial roadways in Jonesboro, Arkansas. The data formed the baseline for future assessment of the impacts of development and population increase on mobility.

2.1.2. GPS Implementation Strategies

For calibration and analysis of data collected by GPS, various methods and software were used in the past. Radford University's GPS website can be used to obtain differential correction data to identify precise location information (RVAMPO, 2000). Trimble's Pathfinder Office Software

was used to transfer the GPS file from the TDC-1 collection unit (RVAMPO, 2000). In general, the raw data of GPS system should contain the time stamp, latitude, longitude, speed, horizontal dilution of precision, and the number of satellites (Hunter et al., 2006). The information on altitude, heading, vertical dilution of precision, and positional dilution of precision may also be collected from GPS receiver.

Faghri et al. (2010) quantified travel time and delay data using a Trimble GPS unit and a laptop with Trimble TerraSync and GPS Pathfinder Office software installed for the identification of the severity of congestion. They conducted the study on all major routes surrounding large population centers in Delaware and identified total peak delay and percent time in delay.

Tracy (2012) conducted a study along US-40 heading east from NJ-54 into Atlantic City in New Jersey to collect passenger travel time. It was concluded that the GPS antenna is capable of recording the latitude and longitude, and speed of the test vehicle every second.

Cafiso et al. (2012) presented a model of motorist behavior through GPS sampling of the positions of several test motorists in terms of speeds on two-lane rural roads. The model could estimate continuous speed profile that depends on the spot geometry, horizontal, and vertical alignment of the road segment. The model was also able to correctly estimate different speeds for two different curves, mean speed, and any desired percentile of the operating speed. A significant correlation between curvature and the standard deviation of speeds was observed in their study. The reported model coefficients were used to predict operating speed on two-lane rural roads in Italy. However, application of the model outside Italy would require a new calibration based on local speed surveys because of the differences in motorist populations, roadway systems, and vehicle fleets.

2.2. Bluetooth Detectors for Travel Time Studies

Travel time data using Bluetooth detection technology captures travelers Bluetooth-enabled devices that broadcast unique identifiers known as MAC addresses (Wasson et al., 2008; Cambridge Systematics, Inc., 2012). Invented in 1994 by engineers from Ericsson, a Swedish company, Bluetooth enables the sharing of music, images, and other data wirelessly over a personal area network (PAN) which is defined by the device's antenna. Many computers, car radios, navigation devices, Personal Digital Assistants (PDAs), cell phones, headsets, and other personal devices are Bluetooth enabled to allow wireless communication between devices. Generally, manufacturers assign MAC addresses to Bluetooth equipped devices.

Bluetooth detector technology uses the MAC-48 identifier format as defined by the Institute of Electrical and Electronics Engineers (IEEE, 2002). Consequently, every Bluetooth device is uniquely identified by a 48-bit MAC address, which consists of six pairs of hexadecimal digits. The first three groups of numbers are known as the organizationally unique identifier, which is specific to the device manufacturer, while the last three groups of numbers are unique to the device.

In Bluetooth travel time measurement systems, the MAC address of every Bluetooth device that is detected is recorded along with a time-stamp. Thus, a MAC address detected at more than one Bluetooth site represents a unique Bluetooth device which traveled from one site to the next, and its travel time may be determined by calculating the difference in the time-stamps. Because the MAC addresses are not tracked when the device is sold within the marketplace, the MAC addresses can be detected and matched without establishing a relationship to the device owner,

therefore keeping the traveling public and their personal or sensitive information anonymous (Cambridge Systematics, Inc., 2012).

Research in the field of Bluetooth technology for travel time measurement has progressed substantially in recent years. Several vendors have developed Bluetooth products to provide travel times to their clients more effectively and inexpensively. The studies reported in this summary exemplify the applicability of Bluetooth detectors for traffic monitoring.

2.2.1. Bluetooth Detector Technology and Its Features

The ability of Bluetooth detectors to capture data depends on their technical specifications, including frequencies and different types of antennas available along with their effective ranges. A radio frequency refers to rate at which radio signals are transmitted. The effective signal range of a Bluetooth device, which is defined by its antenna class, is the range at which other Bluetooth devices may be discovered and connected. Wasson et al. (2008) discussed several key components of Bluetooth detectors, such as a Bluetooth MAC address detector and processor, a radio capable of reading the MAC address, and a Central Processing Unit (CPU) system to forward data to a central location.

The Smart Transportation Applications and Research (STAR) Lab's Bluetooth detectors contain a constant scanning Bluetooth chipset, a processing module to record MACs, and a communication module to transmit data in near real time (Wang et al., 2011). It takes 10.24 seconds at a minimum to discover all Bluetooth devices within the range. During the process in which a Bluetooth device is discovered (inquiring process), the device hops on 32 channels consisting of 16 channel subsets (trains). It takes 0.01 seconds to scan each train. Each scan is repeated 256 times for providing necessary time to collect inquiry responses from other Bluetooth devices. In addition, two iterations of each train occurs due to the specification of at least three train switching, which overall results in 10.24 seconds to identify a Bluetooth device within the range (Woodings et al., 2002).

In contrast to more commonly used radio signals (TV, radio, etc.) which are broadcasted over large areas, Bluetooth detectors sends radio signals over short distances ranging from a minimum of 3 feet to more than 330 feet (Bluetooth, 2013). The radio waves are sent at frequencies from 2.402 GHz to 2.480 GHz as internationally agreed for the use of industrial, scientific, and medical devices (Franklin and Layton, 2000). Class 2 radios found in mobile phones provide ~33 feet range. These devices operate at a very lower power. For example, class 2 radios operate at 2.5 mW or 4 dBm. However, the low power negatively impacts the rate of data transfer, which ranges from 1 Mbit/s to 24 Mbit/s.

Although Bluetooth detectors do not require a line of sight, physical obstacles that obstruct the line of sight between two Bluetooth detectors influence the signal attenuation of a Bluetooth device and reduce the likelihood of getting connected (Logitech, Inc., 2005; Liu et al., 2011). However, Bluetooth signals are able to travel through glass and may propagate off of other reflective surfaces to establish a wireless connection.

Like all wireless connections, Bluetooth detector sends signals that may be susceptible to interception by those who are wishing to access data without permission. Bluetooth detector's automatic connections are a benefit in terms of convenience, but may serve as a gateway through which unwanted data are received. Consequently, manufacturers typically provide the option to enable and disable Bluetooth capabilities on their devices. Commonly known as "discovery mode," this mode enables the device to be detected by other Bluetooth detectors and establish a connection.

2.2.2. Issues and Challenges with Bluetooth Detectors

Bluetooth detection technology can allow up to eight devices to be connected at the same moment by using the adaptive frequency hopping and frequency hopping synchronization (Franklin and Layton, 2000). The probability of interference between any two devices is reduced by frequency hopping synchronization as it is highly unlikely for these two devices to use the same transmitting frequency at the same time. Bluetooth detectors communicate over a PAN or piconet after connecting automatically.

High implementation cost, multiple readings from a single vehicle, and inclusion of bypass trips are some of the issues associated with using Bluetooth detectors for travel time data collection (Koprowski, 2012). Signal delay and non-uniform traffic flow can cause errors in Bluetooth travel time measurements in case of arterial streets (Nelson, 2010; Van Boxel et al., 2011). As it takes 10.24 seconds to detect a Bluetooth device, it can be a source of error for estimating travel times though the inaccuracy decreases as the spacing between Bluetooth detector stations increases (Malinovskiy et al., 2010; Puckett and Vickich, 2010). Wang et al. (2011) observed 2.4 to 11.4 seconds (4% to 13%) of average errors while performing the travel time data collection along the 0.98-mile-long arterial study corridor in Washington. They identified that absolute errors depend on sensor configurations and surrounding conditions, and is independent of length of the study corridor. Their study concluded that longer corridors tend to allow a better performance for this technology based data collection process. A negligible amount of signal degradation occurs when the devices are more than ~6.6 feet apart transmitting wirelessly (Logitech, Inc., 2005).

The operation of Bluetooth detectors can be inversely affected by other higher power devices (802.11b Wi-Fi), cordless phones, two-way radios, and microwave ovens while using the unlicensed 2.4 to 2.483 GHz industrial, scientific and medical spectrum (Fredman, 2002). Frequent dynamic noise occurs due to the interference of established Bluetooth piconets with the test Bluetooth piconet. When two or more Bluetooth detectors try to use same transmitting frequency channel, the signal degradation occurs, such as 5%, 11%, and 21% efficiency loss due to the presence of 4, 10, and 20 piconets, respectively. The transmission failure can also result from frequency collision of two overlapping piconets using the same transmitting frequency at the same time (Lynch Jr., 2002).

The outliers are another source of errors. For freeway data collection, the following situations should be filtered: (1) vehicles exiting and returning to the freeway between two stations, (2) vehicles that stop on the shoulder temporarily, (3) vehicles traveling slowly due to repair requirements, and, (4) vehicles recorded at the upstream station but missed at the following station, detected at the second station traveling in the opposite direction later on in the day (Martchouk et al., 2011). Nelson (2010) preformed a travel time data collection comparison study on local and arterial roads, intersections, and interchanges in Washington, DC. Their study recommended using minimum and maximum travel time filters to identify outliers. However, this procedure is not suitable for the roadways with high variability in travel times throughout the day. Roth (2010) developed a travel time data cleaning methodology collected by Bluetooth detectors based on a time series approach. The study compared the number of outliers detected by modified Z-Test, Grubbs' Test, and Chauvenet's Criterion, and identified that modified Z-Test detected the most outliers. The modified Z-test was, therefore, recommended to identify and remove outliers in an inexpensive way, which require only a single iteration. Malinovskiy et al. (2010) and Puckett and Vickich (2010) have addressed the issue of MAC address groups that are

produced by the data collection units by utilizing the time stamp for the first MAC address in a group as a solution to that problem. Quayle et al. (2010) performed an arterial performance measurement study on Tualatin-Sherwood Road in Portland, Oregon. Their study acknowledged that multiple detections of Bluetooth devices are possible while passing by a data collection unit. They identified that MAC address group sizes depend on the data collection unit to road distance and time duration of the device within data collection unit range. Haghani et al. (2010) suggested using appropriate data collection unit spacing for the minimization of redundant detections for freeways. An average of the detection time can be used in case of multiple detections. According to Wasson et al. (2008), the travel time sample errors are negligible for distances between data collection units that they examined (2-3 miles) on arterial streets.

Though Bluetooth detection technology has been found to have acceptable accuracy to estimate the travel time under homogeneous traffic conditions, there are a few limitations. Pedestrians and bicyclists with detectable devices and buses with multiple Bluetooth devices onboard are sources of outliers (Malinovskiy et al., 2010). The data collected from arterial streets showed a significantly larger variance compared to data from freeways due to traffic signals and vehicle diversion to side roads (Wasson et. al., 2008).

Malinovskiy et al. (2010) investigated Bluetooth MAC address-based travel-time detectors with ALPR sensors indicating that Bluetooth detectors tended to be biased towards slower vehicles. The computed travel time, therefore, can be slightly overestimated.

Extraneous delay sources, such as traffic signals and nearby bus-stops, should be considered to avoid undesirable factors while conducting the travel time analysis on arterial streets (Wang et al., 2011). The length of the corridor can significantly affect the performance of the Bluetooth-based travel time collection system. A short corridor is more prone to errors and inaccurate results for arterial streets (Wang et al., 2011).

2.2.3. Feasibility and Applicability of Bluetooth Detectors

The low cost per unit of data, continuous data collection, and no disruption of traffic are some of the benefits of using Bluetooth detectors as travel time data collection technology. According to a travel time study by Tarnoff et al. (2009), Bluetooth-based method is found to be one of the most cost-effective approaches for travel time data collection. The Bluetooth detectors are found to be hundred times cheaper than equivalent floating car runs for both arterial streets and freeways. Phil Tarnoff, CEO of Traffax Inc., stated in 2010, that the estimated cost per travel-time data point of the Bluetooth detector data was just 1/300th of the cost of comparable floating car data (Bradley, 2010). The Center for Advanced Transportation Technology (2008) performed a travel time data collection and analysis study along I-95 between Baltimore, Maryland and Washington, DC. They estimated the Bluetooth detector based process is 500 to 2,500 times cost effective than floating car data collection based on the data points produced.

Blogg et al. (2010), from an origin-destination (O-D) study, conducted on Centenary Motorway in southwest Brisbane and an arterial street network in north Brisbane between Stafford and Strathpine in Australia, found that the MAC data collection by Bluetooth detector technology is a cost effective way to collect vehicle O-D in small and controlled networks. However, for extensive networks, the MAC O-D data can be cost effectively used as a supplement to the traditional methods.

Wasson et al. (2008) conducted two different field tests in Indianapolis on US-31 and I-69 in early 2008. The study illustrated the feasibility of matching MAC addresses to report travel times. A study was also conducted in Oregon along a 2-mile segment of Tualitin-Sherwood Road

to determine changes in travel time and travel time variability as a result of a signal timing change (dePencier, 2009). Six Bluetooth readers were used to show that both metrics indicated improvement after signal timing changes.

Puckett and Vickich (2010) found out (from a study to identify real time travel time data for arterial streets and freeways) that utilization of Bluetooth detectors on arterial streets is feasible. The accuracy of measuring travel times using Bluetooth detector is an important factor in the decision making processes. Malinovskiy et al. (2010), in their study to measure the travel time on SR-522 in Washington using Bluetooth detectors, found that the devices were representative of the ground truth travel time data obtained from ALPRs.

Haghani et al. (2010) aimed to use Bluetooth detectors as a new and effective means of freeway ground truth travel time data collection by comparing the Bluetooth detector based data with floating car data. They conducted their study on I-95 between Washington, DC, and Baltimore, Maryland and found out that ground truth provided by the new Bluetooth detectors and the actual travel times are not significantly different. KMJ Consulting, Inc. (2010) conducted a study to evaluate the ability of Bluetooth detector to collect and report travel times along I-76 at locations coincident with EZPass tag readers. The study found out that travel times measured by the Bluetooth detector technology are comparable to those obtained by EZPass tag readers. Haseman et al. (2010) collected 1.4 million travel time records over a 12-week period for the evaluation and quantification of travel mobility for a rural interstate work zone along I-65 in Northwestern Indiana. They used Bluetooth detectors to identify travel time delay in work zones.

The Bluetooth detectors can be used to estimate O-D pairs. The system can also be used for route choice (Hainen et al., 2011). Martchouk et al. (2011) used Bluetooth detectors to analyze travel time reliability for the Indiana DOT along I-69 in Indianapolis. It was determined that Bluetooth technology was effective in measuring travel times.

2.2.4. Bluetooth Implementation Strategies

Kim et al. (2010) performed a study to evaluate the accuracy of estimated travel time using various technologies, such as TRANSMIT (RFID) readers, Bluetooth detectors, and INRIX. They concluded that Bluetooth detectors provided accurate results compared to TRANSMIT readers and INRIX. Liu et al. (2011) compared the use of Bluetooth readers to TRANSMIT (RFID) readers and INRIX using data collected along I-287 in New Jersey. The Bluetooth detectors produced the most accurate travel times when compared to the RFID readers and the INRIX data, matching the ground truth more closely. Their study further suggests that Bluetooth detectors can be used to provide accurate travel time.

Haghani et al. (2010) found that the accuracy of the travel speeds in freeways generated from the collected MAC addresses increases with the increase of distance between Bluetooth detectors and the decrease of vehicle speed. Malinovskiy et al. (2010) recommended the detection area on the road should be large enough for the detection of nearly all vehicles with Bluetooth-enabled devices traveling at different speeds. Schneider IV et al. (2010) compared Bluetooth to floating car methods on interstates, urban arterial streets, and state highways. They found that arterial tests had much lower number of matches than the interstate tests. They suggested one to two miles spacing between Bluetooth detector stations for increasing the number of matches. Large detection zones, such as Class 1 radios, can be a source of error in short corridors as any Bluetooth device within the detection range may be detected by the Bluetooth detectors (Vo, 2011). However, according to Malinovskiy et al. (2010), in spite of loss in accuracy in travel

time measurements, larger detection zones provide higher matching rate. This improves the sample size and reduces random error rates for both arterial streets and freeways.

Martchouk et al. (2011) analyzed inter-vehicle and inter-period variability. They combined speed and volume data collected by using microwave detectors with the Bluetooth travel time data. They also developed duration models of travel time to identify when the traffic breakdown occurs.

According to a travel time estimation study by Araghi et al. (2012) on a selected road link in Sauersvej, Denmark, the Bluetooth detector technology provides acceptable accuracy to estimate the travel time under homogeneous traffic conditions. The MAC address can provide the information of type of Bluetooth-enabled device (mobile phone or laptop) referred to as the class of the device and can also be used to identify the type of vehicle carrying that Bluetooth device as a way to separate out motorized and non-motorized traffic.

The sample size of data is another important aspect in providing accurate and up-to-date travel times. The study by Wasson et al. (2008) produced 0.7% to 1.2% match rates (percentage of Bluetooth devices detected at two or more Bluetooth detector locations out of the total traffic volume in the corridor). According to Neal Campbell, CEO of TrafficCast, BlueTOAD system can achieve match rates of 3% to 6% of the traffic stream (Bradley, 2010); which is found to be 4% by another study on arterial streets (KMJ Consulting, Inc., 2010).

Haghani and Young (2010) conducted a study to monitor traffic on I-95 in Maryland using Bluetooth detectors and obtained 2% to 5.5% match rates during a validation test in six eastern states. Wang et al. (2010) obtained 2.2% match rates on arterial streets in their study. According to the study by KMJ Consulting, Inc. (2010), these match rates are sufficient enough to identify travel times accurately. They suggested that, for roadways with 36,000 average annual daily traffic (AADT), 9, 36, and 864 matched pairs per 15-minutes, hour, and day (2% match rate), respectively can provide accurate travel time estimation. However, the percentage requirement increases with the decrease in AADT.

Detection rates are generally comparable to the traffic volume and can be used as a baseline for that particular location (Nelson, 2010). Schneider IV et al. (2010) also identified that match rates are proportional to the traffic volume on arterial roads. They found that the proportion of Bluetooth devices per vehicle does not depend on the time-of-the-day.

Asudegi (2009) conducted research to identify optimal number and location of the Bluetooth detectors in a network for travel time data collection with a high reliability. The study assumed Bluetooth penetration rate to be 3% to 5% of normal traffic streams of arterial streets and freeways. Haghani et al. (2010) obtained the Bluetooth penetration rate as approximately 5% for freeways. Hainen et al. (2011) performed a route choice and travel time reliability study on arterial streets in Indiana. They estimated that 7% to 10% of passing vehicles have detectable Bluetooth devices for arterial streets. Brennan Jr. et al. (2010) performed a study on I-65 in Indianapolis to assess the influence of vertical placement of Bluetooth detectors on data collection quality. They assumed 5% to 10% of the vehicle population on the freeways has MAC addresses that can be discovered.

Porter et al. (2010) conducted a study to assess the suitability of different antennas to support a Bluetooth based travel time data collection system on Oregon Route 221 (Wallace Road NW) in Salem, Oregon. They found that vertically polarized antennas with gains between 9 and 12 dBi are good for Bluetooth based travel time analysis. According to Malinovskiy et al. (2010), two omni-directional antennas placed at the same location on opposite sides of the road provide the best detection rate. Multiple readers at one site may increase the number of detections.

Combinations of sensors in tandem increase the accuracy of the detection and matching rates and reduce error in most cases on arterial streets (Wang et al., 2011).

The height of the Bluetooth detector has an important role in detection rate. Brennan Jr. et al. (2010) conducted a study by placing five Bluetooth detectors at different heights ranging from 0 to 10 feet along I-65 in Indianapolis to identify the sensitivity of sample size to sensor placement. They concluded that 7.5 feet and 10 feet produced similar results while the others performed poorly. However, further research is necessary to test if optimal height depends on site characteristics.

The performance of Bluetooth detector technology in estimating travel times has been compared to floating car methods and RFID as an accurate and cost-effective alternative. In 2010, Schneider IV et al. (2010) completed a study comparing Bluetooth to floating car methods considering interstate highways, urban arterial streets, and state highway segments. The number of matches for the arterial street tests was much lower than the interstate tests. To increase the number of Bluetooth matches, which is the number of MAC addresses detected at more than one site, it was suggested that Bluetooth stations should be installed one to two miles apart.

Moghaddam and Hellinga (2014) examined the application of Bluetooth detectors to acquire travel times on arterial streets as it is challenging due to frequent interruptions in the traffic flow because of traffic signals. They combined micro traffic simulation with Monte Carlo simulation to synthesize measurement errors. The results showed that the mean travel time error is essentially zero for all traffic conditions. However, the variance of the error varies as a function of the traffic conditions. A multivariate regression model was developed to quantify the standard deviation of the travel time measurement error as a function of the traffic factors, and, using this model showed that under some conditions, the 95% confident interval of the travel time measurement error may reach 25% of the true mean travel time.

2.3. INRIX for Travel Time Studies

INRIX, a software and Desktop-as-a-Service (DaaS) company established in 2004, provides a variety of mobile applications and Internet services pertaining to traffic and motorist services. Currently, more than 200 customers and industry partners worldwide choose or use INRIX data.

INRIX offers real-time, predictive and historical traffic information, real-time incident and weather safety alerts to transportation agencies to provide more complete data-powered solutions for measuring system performance, streamlining operations or delivering new and improved services. Currently, 46 states are using their free INRIXTraffic. Also, 16 states in the US I-95 Corridor Coalition teamed with INRIX to improve traffic Operations (INRIX, 2014). Texas Transportation Institute fuels its annual Urban Mobility Report using INRIX data (TTI, 2012; INRIX, 2014).

INRIX monitors 260,000+ miles of roads in real-time (24x7) including all interstates, other major roads nationwide, major arterial streets and city streets in all 52 cities with populations over 1 million people. It also detects location and incident type, monitors status and communicates severity of abnormal traffic/travel conditions nationwide (INRIX, 2014).

The INRIX Traffic Scorecard provides a comprehensive analysis of the state of traffic congestion. INRIX 2007 Traffic Scorecard Annual Report was transformative in its ability to illustrate how “Big Data”, crowd-sourced in real-time from actual vehicles and mobile devices traveling through road networks, provide a comprehensive, consistent and timely measure of traffic congestion nationwide. The data is used to conduct studies at a macroscopic level.

2.3.1. Feasibility and Applicability of INRIX

Independently validated by the I-95 Coalition Vehicle Probe Project, INRIX offers 100% detection of all freeway slowdowns, travel time accuracy above 95% and 99.9% availability. The conditions of all freeways are calculated and updated every minute (INRIX, 2013).

The University of Maryland team and State Highway Agency planned and investigated the effect of data source on freeway travel time reliability assessment and have unrestricted access to the database on a major corridor covering sections of I-95 South, I-495 West and I-270 North. The area is covered by a number of permanently installed Bluetooth sensors. At the same time, SHA has procured INRIX data on the same corridor. Since 2008, the University of Maryland team has published several validation reports on INRIX data performance on both I-95 and I-495 as part of the I-95 Corridor Coalition Vehicle Probe Project (VPP). Their validation results showed that INRIX meets quality standards to be used as a source for travel time data.

Chase et al. (2012) compared 5-min speeds from microwave radar and acoustic sensors with link speeds from GPS probes for both directions at five freeway locations. Systematic differences were found at one location. Floating car GPS runs were performed to confirm that the systematic error lay in the point speeds. They presented a comparative evaluation of reported speeds from collocated point- and link-based speed detection systems at the five bi-directional freeway locations. Systematic speed differences occurred at nearly all study locations, but the mean speed difference was unique to each site. Speeds from GPS floating car runs closely matched INRIX speeds at locations with large speed differences between INRIX and Traffic.com.

Jia et al. (2013) evaluated alternative technologies to estimate travel time along a segment of I-91 in Western Massachusetts where traffic volumes and corresponding sample sizes are expected to be relatively low. Their means of data collection included GPS technology employed by INRIX, Bluetooth technology and field data collected by another vendor, and, BlueTOAD along the I-91 study site. Data collection using a license plate based method was devised to provide “ground truth” travel time against which the results of the INRIX and Bluetooth technologies were compared and evaluated. The data analysis showed that sufficient sample sizes were collected and that the accuracy of travel times estimated from data provided by both vendors (i.e., GPS-based INRIX and Bluetooth-based BlueTOAD) is acceptable since their mean absolute percentage errors (MAPE) were consistently less than 6%.

2.4. Limitations of Past Research

In the past, research has been done to validate travel times obtained from various sources such as GPS probes, Bluetooth detectors and INRIX based on corridor level analysis and not based on link level analysis. The characteristics of a corridor vary from one link to another link along the corridor.

Previous research has shown that Bluetooth detectors can be effectively used for travel time studies on freeways but only a few researchers have worked on arterial streets and the accuracy of travel times obtained for them.

Further, past studies considered travel time runs aggregated for short time intervals. The variations within these intervals may have an effect on accuracy and identification of suitable technology for travel time data collection.

This report, therefore, focuses more on the arterial streets although travel times on a freeway have also been included. Comparisons were done at link-level for each travel time run. Also, the role of network characteristics on percent difference in travel time data has been researched in this study.

CHAPTER 3: DATA COLLECTION AND SOURCES

To capture travel time information and to compare the travel times from various data sources such as manual floating car method, GPS floating car method, Bluetooth detectors and INRIX, six study corridors comprised of five arterial roads and one interstate freeway corridor in the city of Charlotte, North Carolina were selected for research. The corridors were selected such that they cover major areas surrounding the Charlotte Center City (the Central Business District / Uptown / Downtown area) with major commercial and industrial zones (Figure 1). Table 1 summarizes the characteristics of each selected corridor. The following criteria were considered to select the study corridors.

1) Corridor must be at least 5 miles in length
2) Corridor should be part of region's bus network with time schedule of bus service on weekdays or weekends
3) The AADT, the number of lanes, the type of corridor, and speed limit should represent characteristics of typical urban areas.

The characteristics of study corridors were made sure to be different so as to test the effectiveness of various technologies in collecting data under different conditions. One corridor is interstate freeway (I-85), which is an express bus route providing service on a typical weekday. Two corridors are along selected major arterial streets (bus routes 11 and 20), while the remaining three corridors are along minor arterial streets (bus routes 12, 14 and 22).

The travel time data was collected for two days along each corridor. Travel times for different time periods were captured to evaluate the effectiveness of the methods and technologies in collecting data by time period. It was collected from 7 AM - 9 AM, 11 AM - 1 PM, and 4 PM - 6 PM on day 1 and 7 AM - 10 AM and 3 PM - 6 PM on day 2. With Charlotte Uptown as center, the direction of travel is identified as either inbound (towards uptown) or outbound (away from uptown). In this study, 7 AM - 10 AM and 3 PM - 6 PM are considered as morning and evening peak hours, respectively.

Table 1: Characteristics of the Selected Study Corridors

Bus Route Number	Corridor Name	Type	# of Lanes	AADT	Speed Limit (mph)
11	North Tryon St	Major Arterial	3	25,000-30,000	45
12	South Blvd	Arterial	2	20,000-25,000	40
14	Providence Rd	Arterial	2	30,000-40,000	45
20	Sharon Rd	Local	2	14,000-20,000	35
22	Graham St	Arterial	2	14,000-20,000	45
I-85	I-85	Freeway	4	30,000-60,000	65

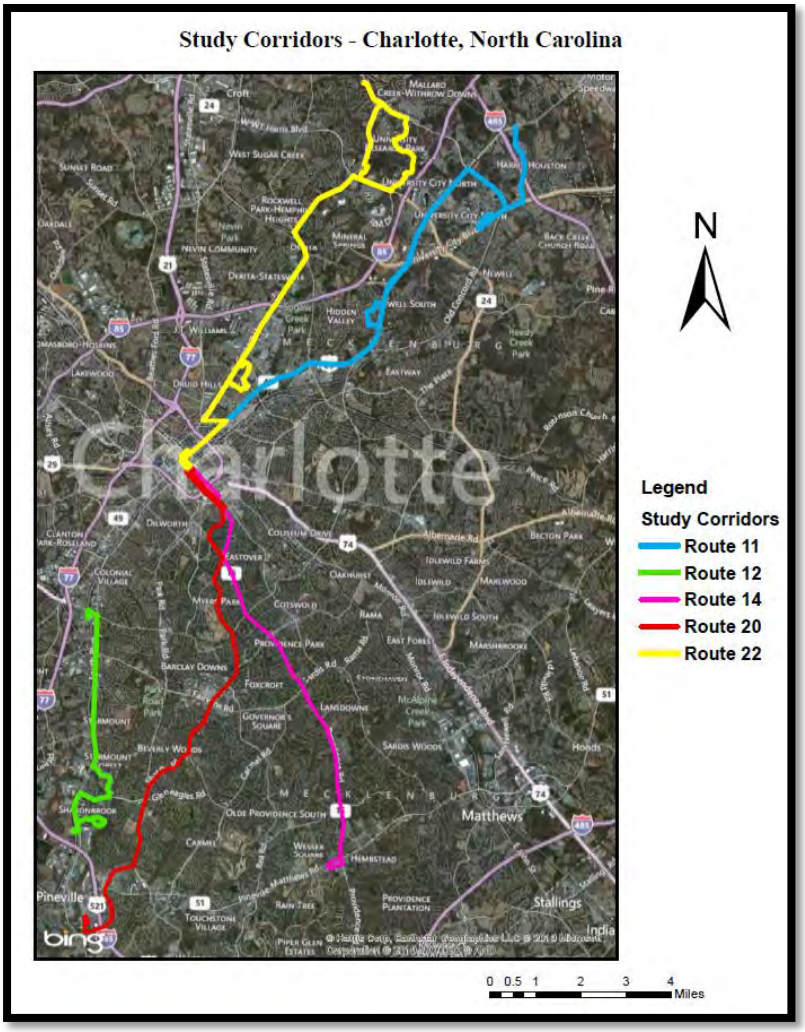
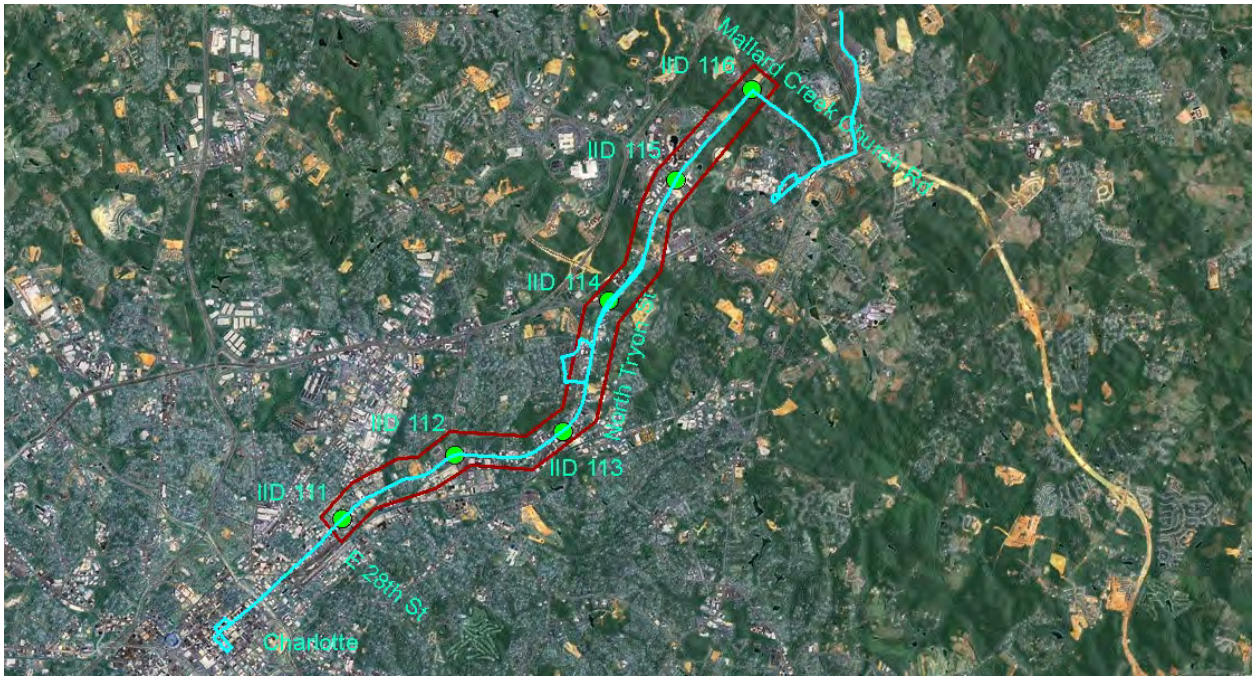


Figure 1: Selected Study Corridors in Charlotte, North Carolina

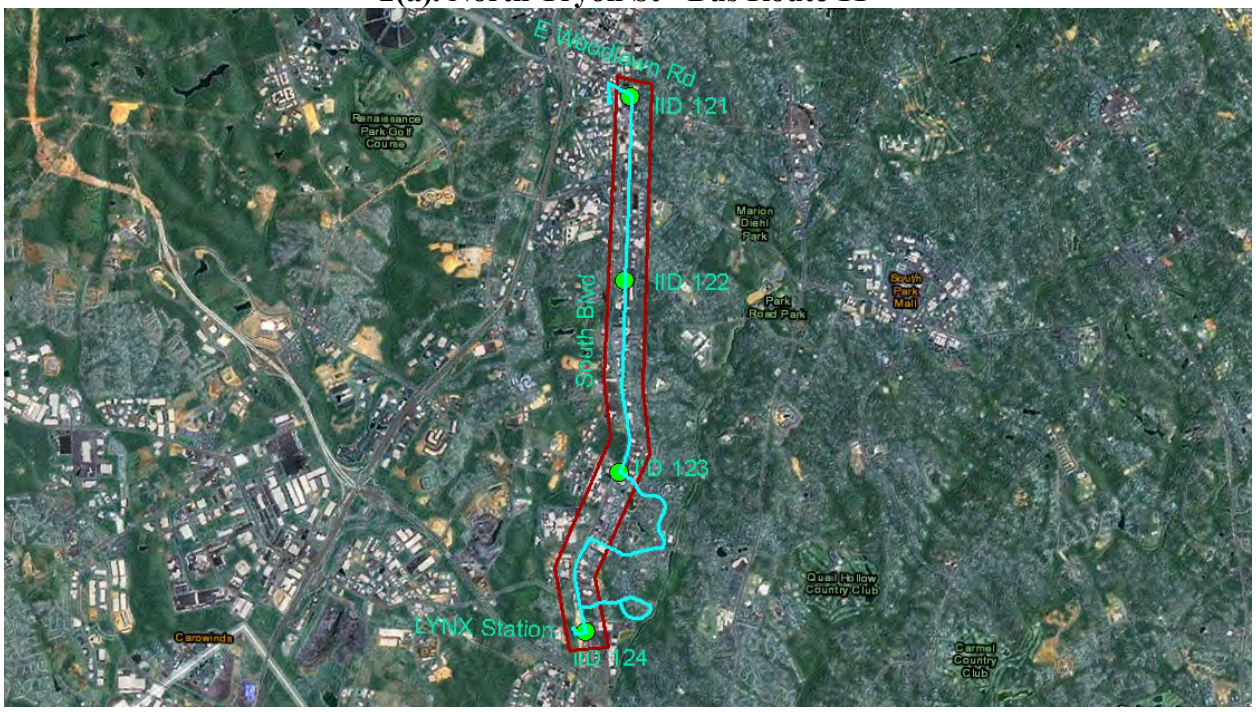
3.1. Manual & GPS Probe Vehicle for Travel Time Data Collection

Travel time data was collected for selected sections along selected corridors using floating car method (Figure 2). In this study, the data collected manually was considered as the ground truth. For the manual data collection, travel time data collection sheets were created for each study corridor, for both inbound and outbound direction. Each paper form contained all intersections along each selected study corridor where the arrival times are noted.

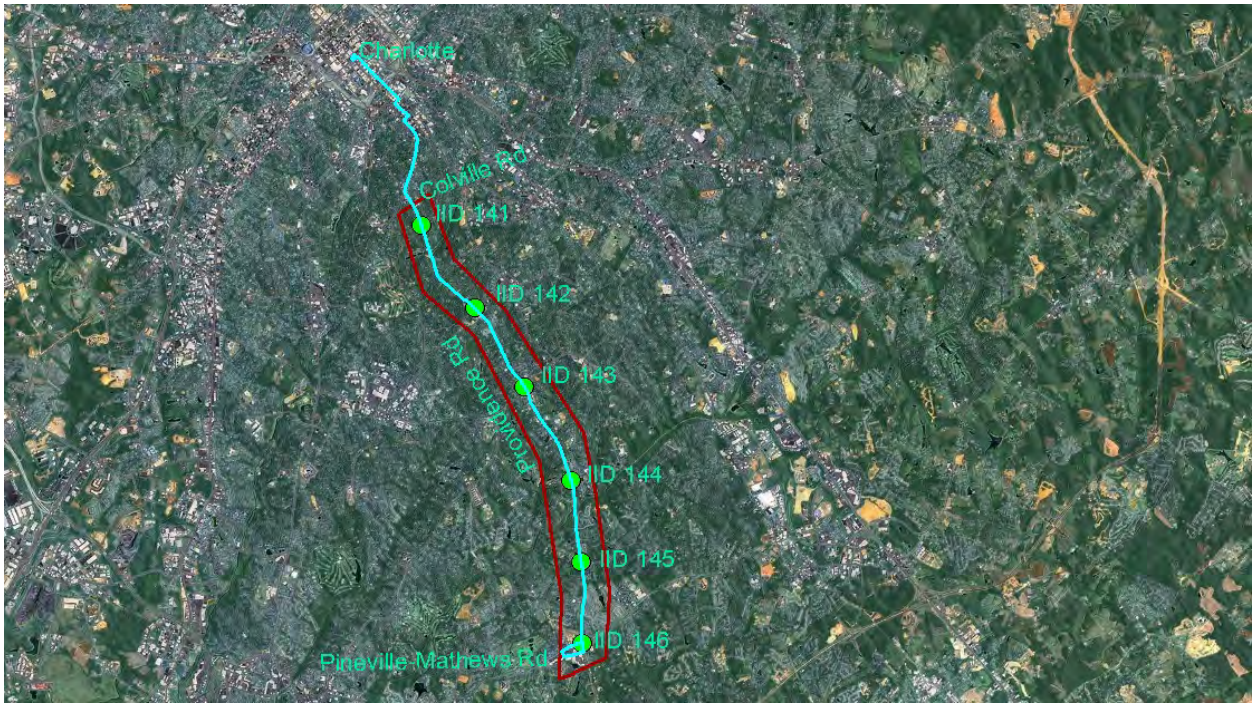
The distance from one intersection to the next intersection (or location) is defined as a section. The intersections that were used as the start and end of a corridor are identified based on the location of the Bluetooth detectors and Traffic Message Channel (TMC) codes (points where INRIX data are available). The manual data collected are tabulated in the spreadsheets separately for each run, section and corridor. The times noted at each intersection were used to compute travel times between each intersection along each corridor for morning, afternoon and evening peak hours individually.



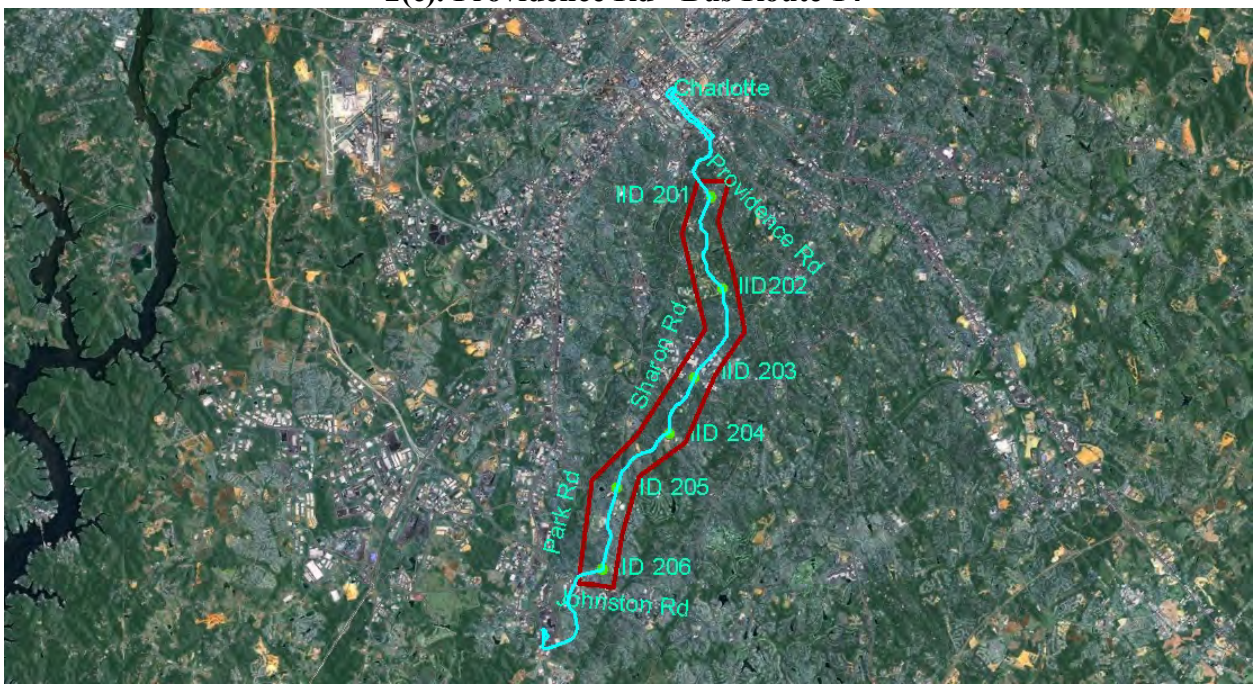
2(a). North Tryon St - Bus Route 11



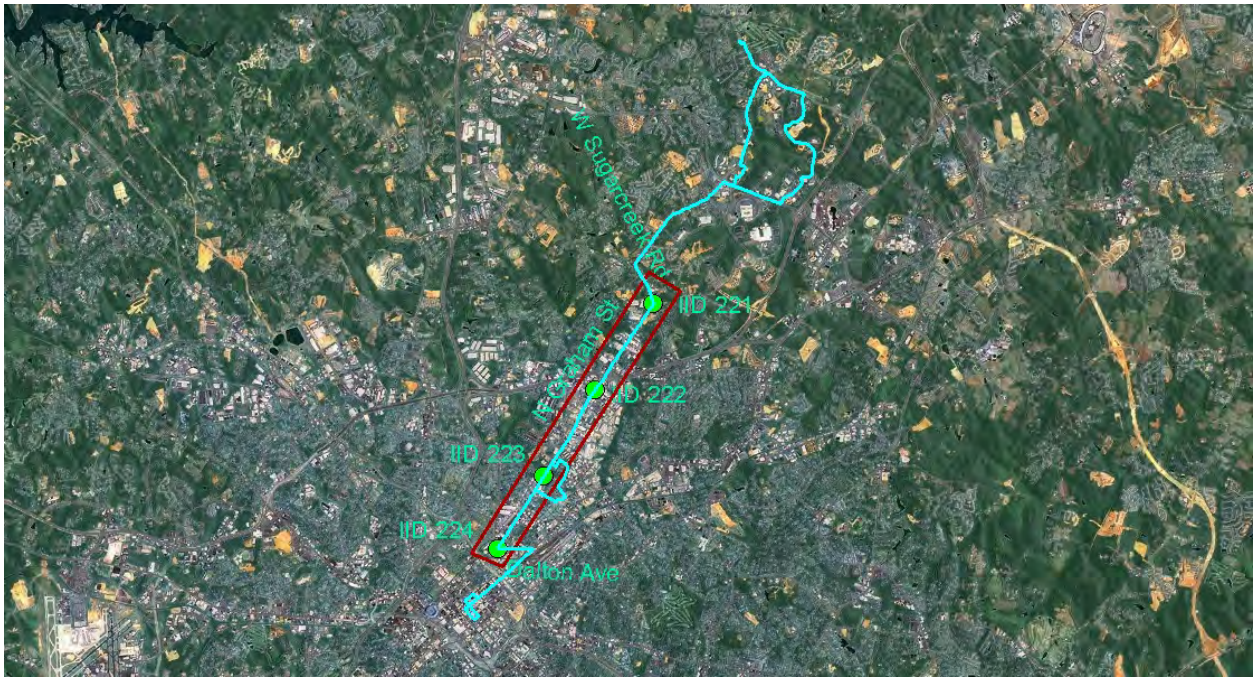
2(b). South Blvd - Bus Route 12



2(c). Providence Rd - Bus Route 14



2(d). Sharon Rd - Bus Route 20



2(e). N Graham St - Bus Route 22

2(f). I-85 - Express Bus Route

Figure 2: Selected Study Corridors with Data Collection Points

In addition, a GPS unit was placed in the floating test car. The GPS unit was attached to a laptop in the car to control the runs and download the data as and when required. PC Travel Suite was used to process travel time and delay data between the selected intersections of all six study corridors. This software package has two portions: GPS2LT2 and PC-Travel. While GPS2LT2 collected the field data in GD2 format, PC-Travel processed the data to compute travel speeds and travel times. To get accurate data, GPS unit was detected by at least 3 satellites to locate the car at the right coordinates. TMC codes for the intersections that have Bluetooth detectors installed are exported into the PC Travel software using GIS based files (Figure 3). With the help of these TMC codes the travel times are collected for each section for different runs during different times of the day. The computed details were exported as an excel file.

In the floating car, three trained technicians participated in the field data collection during each run (Figure 4). The first person noted the arrival time on the sheet manually. The second person captured data at the same location using GPS and also ran the stop watch to let the first person note down the time at the start and end of each section. The third person drove the vehicle within the speed limits on a particular corridor.

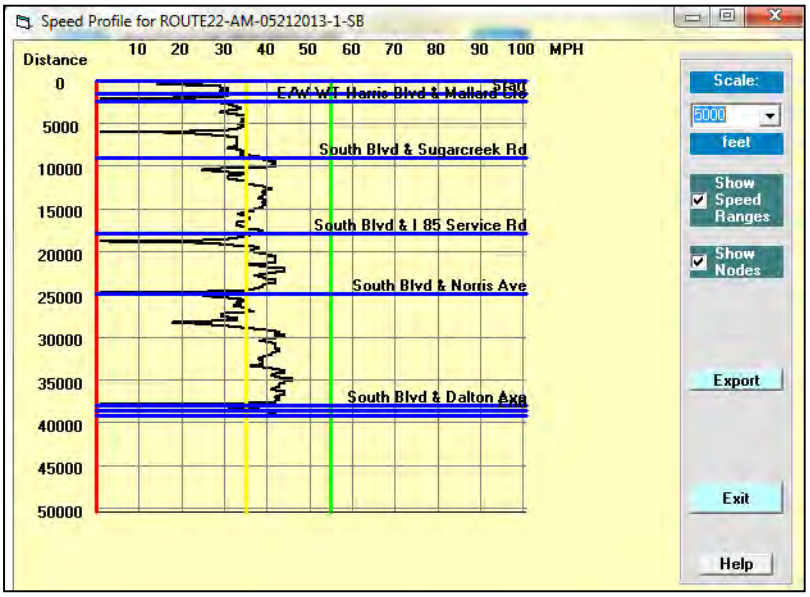


Figure 3: Travel Time Information by Distance using GPS from PC Travel Suite

Figure 4: Trained Technicians Collecting GPS and Manual Travel Times

3.2. Bluetooth Detectors for Travel Time Data Collection

Travel times were captured using Bluetooth detectors that were placed at 5 to 6 intersections along each study corridor. Six Cross Compass (dual Bluetooth and Wi-Fi) detectors with 4GB Acyclica USB Flash Drives, through the use of 2.4GHz omni-directional 8Dbi antennas, were used for Bluetooth data collection. The Bluetooth detectors were provided with Location ID (identifier referring to the specific location of the device), Group ID (identifier referring to a group such as intersection or arterial street), Device Name, Device Description, and Owner information prior to each data collection process. Time Synchronization is a very important factor when collecting data using Bluetooth detectors.

The Bluetooth detectors could encrypt the data at the device level in order to maintain truly anonymous data and provide information using a secure 256-bit hash. As this hash is one-way and each device uses the same algorithm, matching using the encrypted string was as simple as matching individual MAC addresses. The detectors could also provide data in plain text in the form of 6 octets. For this study, the data was collected in both encrypted and plain text format.

The Bluetooth detectors were installed at 1- to 2-mile intervals along each corridor. The detectors were installed near the intersection for easy access of power from the signal cabinet controller or traffic monitoring camera box with the help of Charlotte Department of Transportation or North Carolina Department of Transportation staff. As one of the research objectives was to compare travel times from different sources, the signalized intersections for the installation of Bluetooth detectors were selected in such a way that the position of TMC codes (points where INRIX data are available) matched with the position of these intersections. As mentioned earlier, manual and GPS data was also gathered at the same points.

The mounted height of the antenna to capture data using Bluetooth detectors varied between 7.5-10 feet along the arterial streets (Figure 5). However, the mounting height along I-85 varied between 10 to 15 feet as the traffic monitoring camera boxes were at higher elevation than the ground level. Data was collected using the Bluetooth detectors, continuously for at least 48 hours, for each section along each corridor. They were installed the day before the collection of manual and GPS data (Figure 6). The Bluetooth detectors were uninstalled the day after the manual and GPS data collection was completed.

After uninstalling the Bluetooth detectors, raw data was downloaded from the flash drives connected to the detectors. The data were then uploaded to Acyclica Analyzer website (https://cr.acyclica.com/) for processing the raw data. From the same website, travel times were noted down by the run and by time-of-the-day with reference to the manual times obtained from floating car method for each section along each corridor. The detections and travel times in this case are for the entire duration of travel time run (example, from 8:00:00 AM to 8:03:00 AM for a section along a corridor). Figure 7 shows the travel time variations for section 3 of Route 22 (Outbound). Travel times for each section are shown separately for all the days the device was installed. By selecting the required time and direction of run, the average travel time for all the vehicles at that particular time was noted down.

For an accurate estimation of travel times from Bluetooth detectors (overcome the effect of data outliers), a filtering technique based on minimum speed (20 mph) and maximum speed (speed limit + 10 mph) on a corridor was developed and applied. The minimum speed reflects maximum travel time and helps eliminate those walking, bicycling, using a bus, or waiting prior to complete their trip. The maximum speed reflects minimum travel time (exclude those who drive very aggressively on the roads). Based on the minimum and maximum speeds, travel times are computed and the data obtained from the raw data from Bluetooth detectors was processed

for each section. The use of ±1.5 min, ±2.5 min and ±5 min as filter range for each travel run was also examined. These filter ranges were applied to the run time for each travel run. Consider a manual run that starts at 8:00:00 AM and ends at 8:03:00 AM on a particular section. For filter range of ±1.5 min, the samples detected by the "from detector" during 7:58:30 AM to 8:01:30 AM for start and by the "to detector" during 8:01:30 AM to 8:4:30 AM for end are taken into consideration for that particular run. Based on these filter ranges, the average travel times for each run was collected from Bluetooth detectors. Microsoft SQL Server was used to filter and note down the average travel times.

Figure 5: Bluetooth Detector (Left) and Antenna Installed by the Research Team (Right)

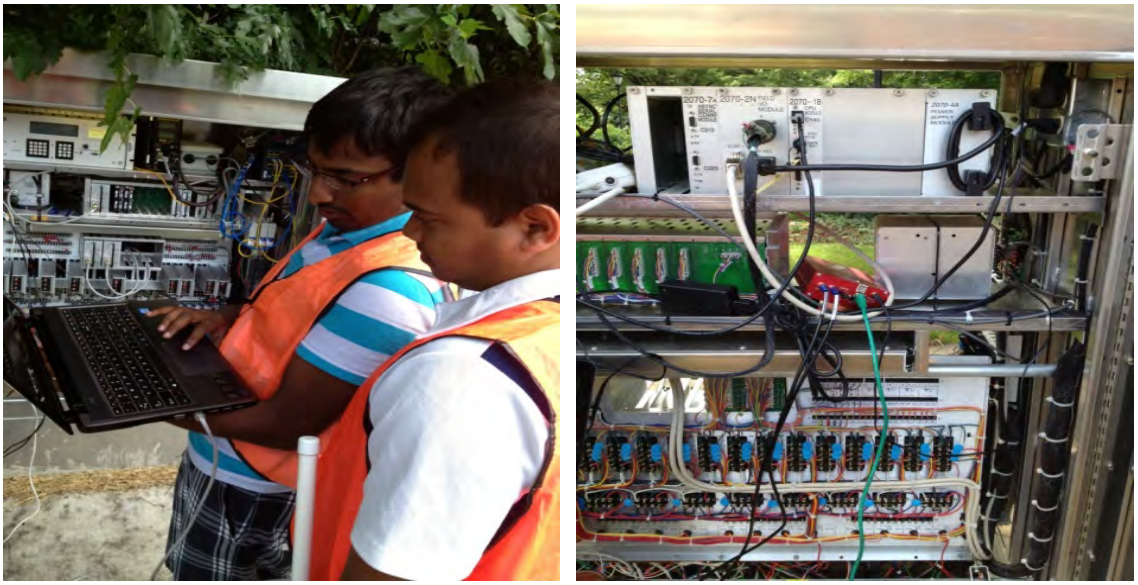


Figure 6: Installing the Bluetooth Detectors in the Signal Control Cabinet

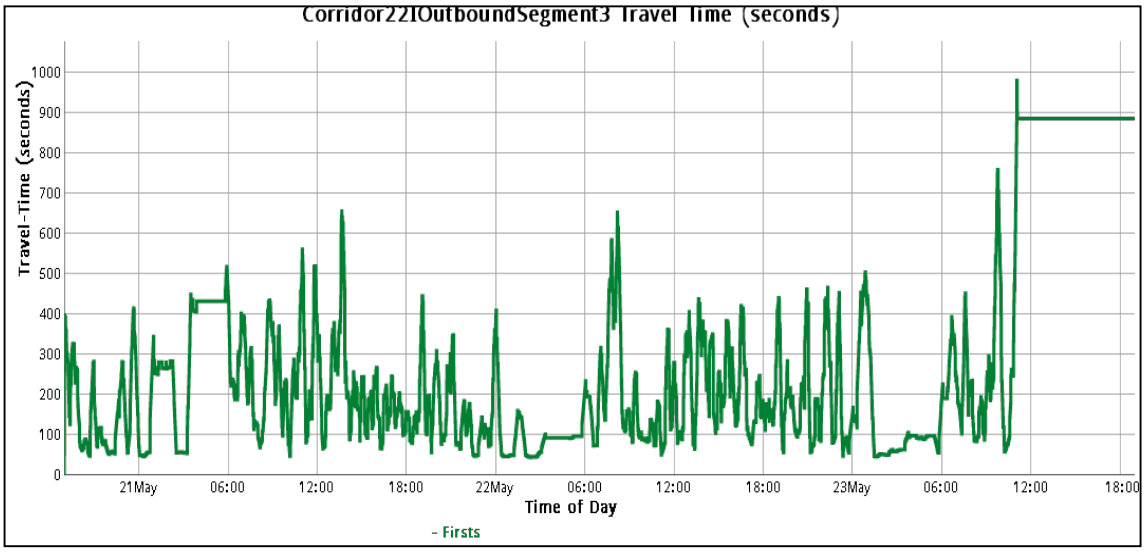


Figure 7: Travel Time Variations for Outbound Section 3 of Corridor 22

3.3. INRIX for Travel Time Data Collection

Access to the INRIX data is granted once a member agency has signed a Data User Agreement. INRIX delivers files to the customers via a Web Services Application Programming Interface (API). All API requests are made via Hypertext Transport Protocol (HTTP). Requests were made to obtain data for the same days on which manual and GPS data were collected, for each selected study corridor through the web interface. The raw data files were received in .CSV format. The raw data file has Traffic Message Channel (TMC) code (tmc_code), time-stamp (measurement_tstamp), speed (speed), average speed (average_speed), reference speed (reference_speed), travel time (travel_time_minutes) and score (confidence_score). Each field in the raw data file is briefly described below (INRIX, 2013).

1. Traffic Message Channel (TMC) - defines section identity of the roadway segment.
2. Speed - current estimated space mean speed for the roadway segment in miles per hour.
3. Average speed - historical average mean speed for the roadway segment for that hour-of-the-day and day-of-the-week in miles per hour.
4. Reference speed - calculated “free flow” mean speed for roadway segment in miles per hour. It is the 85th percentile point of the observed speeds on that segment.
5. Travel time - current estimated travel time it takes to traverse the roadway segment in minutes.
6. Score - an indicator of data type (30 indicates real-time data; 20 indicates real-time data across multiple segments; 10 indicates historical data).

The data from INRIX was obtained for all the study corridors for the entire data collection period (Figures 8 & 9). For better comparison of methods and technologies for travel time data collection, the travel time from Bluetooth detectors and INRIX were extracted for each travel time run on each data collection day.

Based on the start and end times of the manual runs, travel times are collected for all the six study corridors in both inbound and outbound directions. As an example, if the test car travelled

along a section from point “A” and arrived at 8 AM at point “B”, the travel time at point “B” was extracted at 8 AM from Bluetooth detectors and INRIX for analysis and accurate comparison.

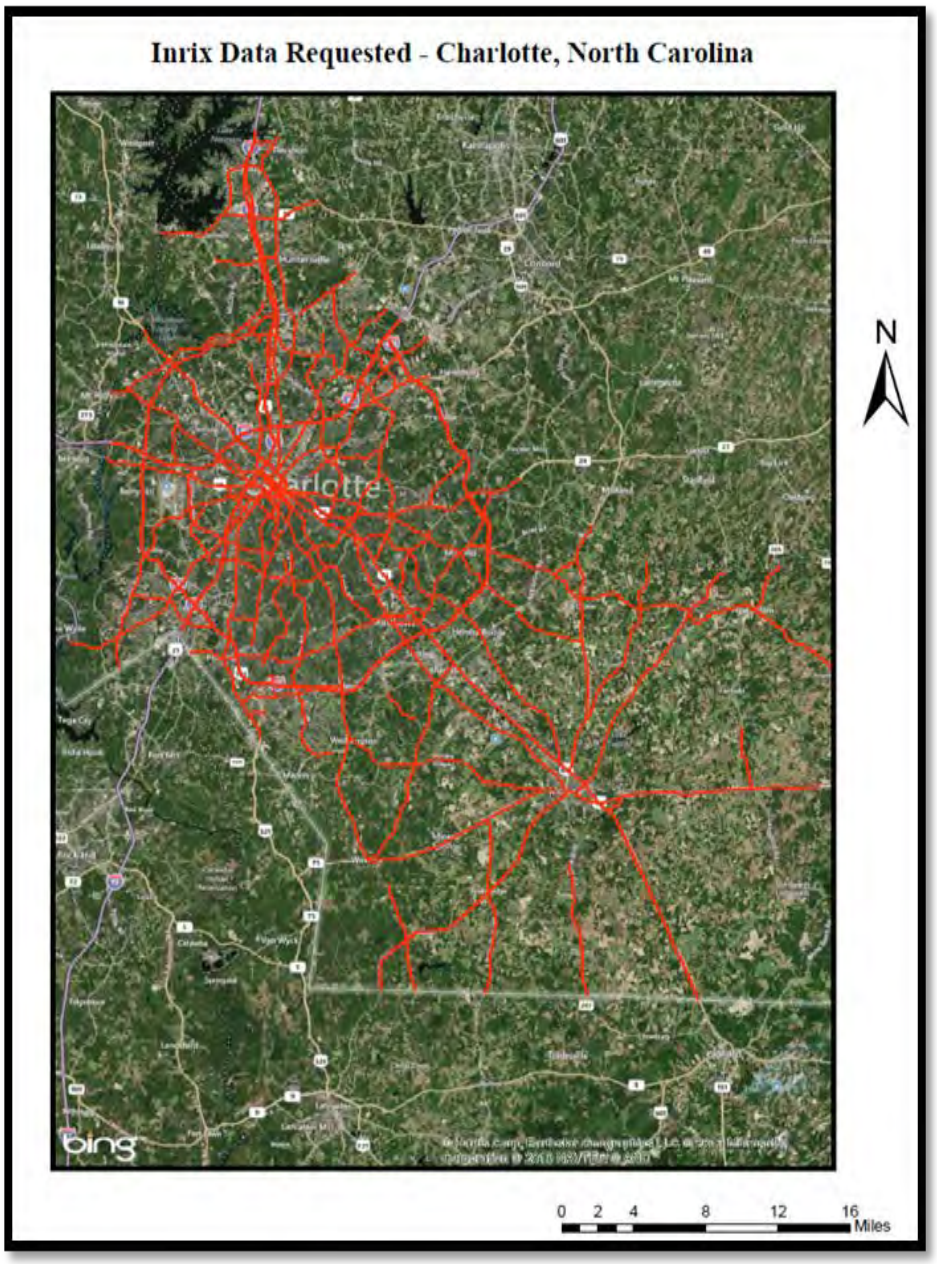


Figure 8: INRIX Data Network for Charlotte, North Carolina

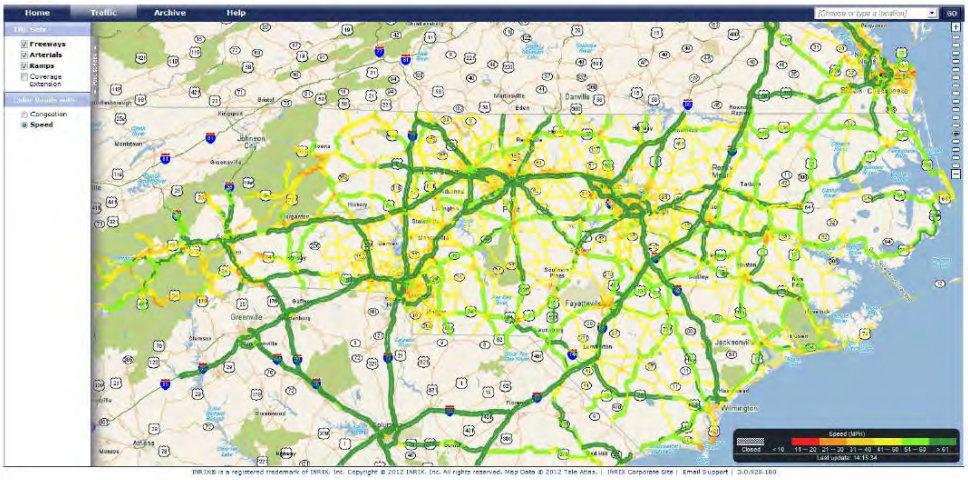


Figure 9: INRIX Data Showing Traffic Trends for North Carolina
(Source: www.ritis.org)

CHAPTER 4: RESULTS AND ANALYSIS

The travel times collected manually, using GPS unit, Bluetooth detectors and INRIX are compared for each section for different time periods. In case of Bluetooth detectors, travel times obtained from both Acyclica filtering technique and filtering technique proposed in this study were used in comparison with other sources. In addition, the role of spacing between intersections and on-network characteristics on travel time difference obtained from the aforementioned sources is discussed in this chapter.

4.1. Travel Time Comparison based on Acyclica Filtered Bluetooth Detector Data

The travel times are compared at a micro-level for each run along each section of each corridor for different time periods. Table 2 shows travel times collected manually and the percentage difference observed from the GPS unit, Bluetooth detectors and INRIX during mid-day and evening peak periods on day 1 along South Blvd study sections. Similarly, Table 3 shows data collected on day 1 along I-85 study sections.

It can be noticed from Table 2 and Table 3 that travel times from GPS are very close to those collected manually. This can be accounted to the fact that the GPS travel times have been collected from the same probe vehicle that was used for the manual data collection. While travel times from Bluetooth detectors and INRIX are fairly close to manual travel times along I-85, travel times from Bluetooth detectors are observed to be significantly higher on sections along South Blvd (Table 2) and other arterial streets. Appendix A summarizes comparison of travel time collected on different days using various technologies / sources for all selected study corridors.

To better assist in comparing the results, the percentage difference in travel time from GPS units, Bluetooth detectors, and INRIX when compared to manual data was computed for each run and section. They were categorized into six percentage difference range categories (0-10%, 10-20%, 20-30%, 30-40%, 40- 50%, and >50%). The numbers of samples (frequency) that fall in each category were summarized for each section. Figure 10 shows the number of samples in different travel time ranges (range of percentage difference in travel times from various sources when compared to travel times collected manually) by study corridor.

Table 2: Mid-day and Evening Peak Runs along South Blvd Inbound Direction

ID	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/29/2013	Run 1 (Time) 11:15 AM				Run 2 (Time) 11:49 AM				Run 3 (Time) 12:17 PM			
1	82.5	0.6	8.7	89.2	91.1	1.0	11.8	77.2	90.0	1.1	31.3	144.4
2	128.3	0.5	1.9	54.7	115.8	0.2	15.0	77.4	137.5	0.4	-7.1	98.5
3	323.4	0.2	-40.4	-40.1	323.8	0.1	-35.0	-18.4	246.7	0.5	-14.6	-7.9
4	126.6	0.3	-24.2	-27.1	123.9	0.9	-17.2	19.2	119.8	-2.3	-22.4	-18.4
5/29/2013	Run 1 (Time) 4:46 PM				Run 2 (Time) 5:28 PM				Run 3 (Time) 6:20 PM			
1	150.5	16.3	-36.5	-12.6	184.0	-3.8	-49.7	-12.3	173.0	1.2	-46.5	-6.7
2	146.3	36.7	5.0	46.4	225.8	-0.4	-22.9	-3.0	211.1	0.4	-32.4	-5.7
3	244.2	-40.2	-11.1	-13.3	319.8	0.1	-46.0	-26.8	380.2	-0.1	-31.8	-43.2
4	157.9	-43.6	-16.8	-50.0	163.1	0.6	-37.1	-27.0	146.5	0.3	-50.9	-26.2

Table 3: Mid-day and Evening Peak Runs along I-85 Inbound Direction

ID	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/25/2013	Run 1 (Time) 11:03 AM				Run 2 (Time) 11:28 AM				Run 3 (Time) 11:51 PM			
1	91.2	-0.2	28.1	-38.3	91.5	-1.6	114.4	-38.5	91.7	-0.8	28.0	-39.0
2	92.6	-0.6	-7.6	-38.4	92.6	0.4	-57.9	-33.9	91.2	-0.2	-8.6	-37.5
3	48.6	-1.2	-17.3	-16.5	48.7	-3.5	-19.9	-16.6	50.6	-1.2	-20.6	-24.9
4	104.3	-0.3	-14.9	2.4	102.3	-0.3	-15.0	6.6	105.4	-0.4	-16.9	3.0
6/25/2013	Run 1 (Time) 4:07 PM				Run 2 (Time) 4:33 PM				Run 3 (Time) 5:13 PM			
1	90.7	0.3	-0.1	-27.0	90.8	0.2	29.3	-37.2	90.1	1.0	30.3	-37.3
2	94.1	1.0	-10.1	-33.3	90.3	-0.3	-5.6	-37.3	81.4	2.0	4.7	-34.5
3	53.4	3.0	-27.0	-25.1	49.3	-0.6	-19.7	-22.5	50.1	1.8	-22.2	-26.1
4	104.5	-1.4	-15.0	12.5	102.3	-1.3	-12.6	2.4	103.6	-0.6	-15.6	2.2

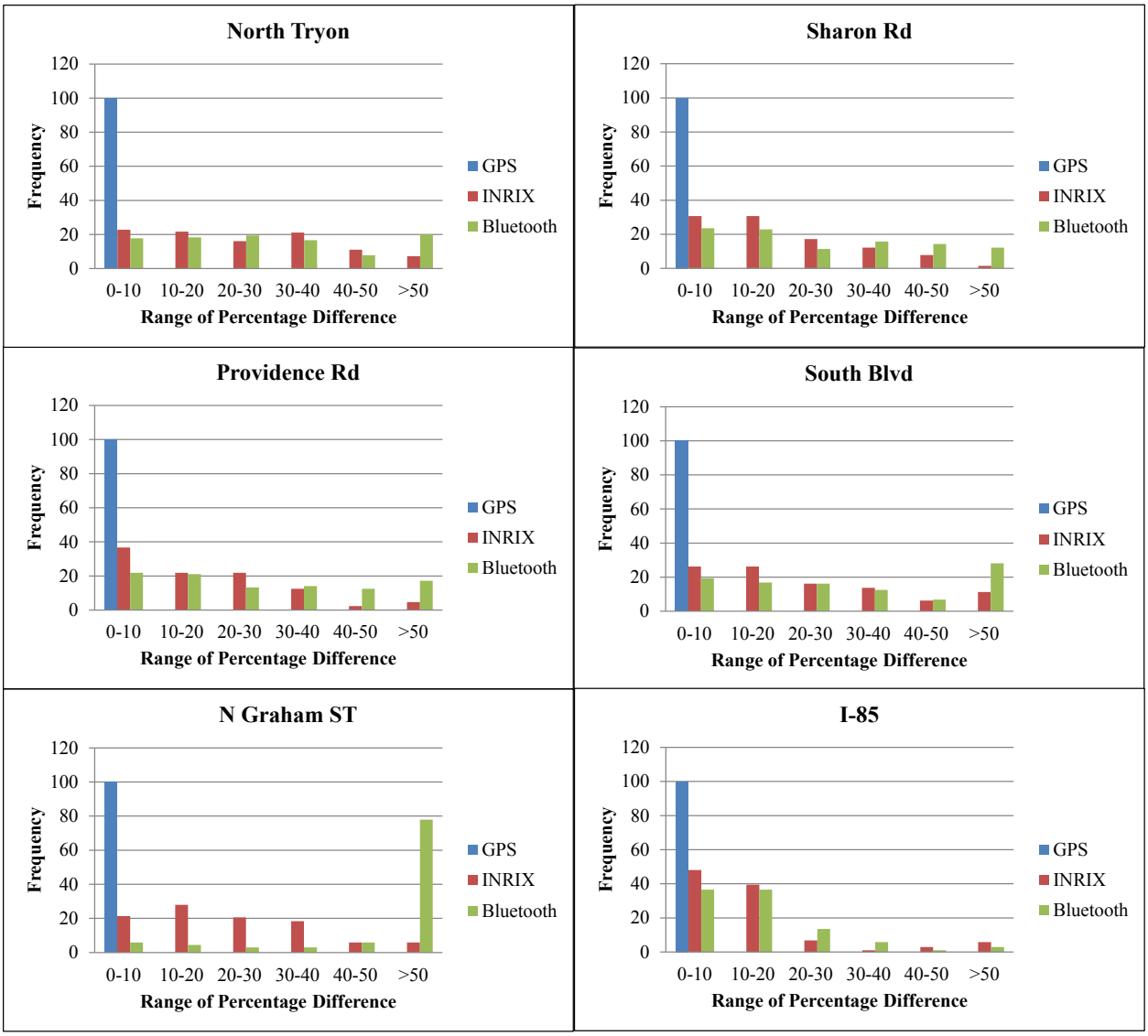


Figure 10: Percentage Difference in Travel Time for Different Corridors

From Figure 10, travel time obtained manually and from GPS units are close to each other as the percentage difference is always less than 10% for all the six study corridors. The figure also reveals that travel times from Bluetooth detectors and INRIX differ from manually collected data. The percentage difference is reasonably high in some cases. For instance, out of the 408 samples gathered along N Graham St, more than 100 samples have percentage difference greater than 50%. To examine the performance over time and account for the effect of traffic on performance, the results obtained were summarized by time period of data collection (Figure 11).

The percentage difference shown in Figure 11 for GPS unit, Bluetooth detectors, and INRIX are in comparison to manually collected travel time. N Tryon St, South Blvd and Providence Rd (relatively high traffic volume streets) showed higher percentage difference during evening peak period (almost 30%, 25%, and 45%, respectively) in case of INRIX data. N Graham, Sharon Rd, and I-85 showed maximum percentage difference during peak periods in case of Bluetooth detectors. For N Graham St, the percentage difference varied by more than 200%. These findings are consistent with those from Figure 10.

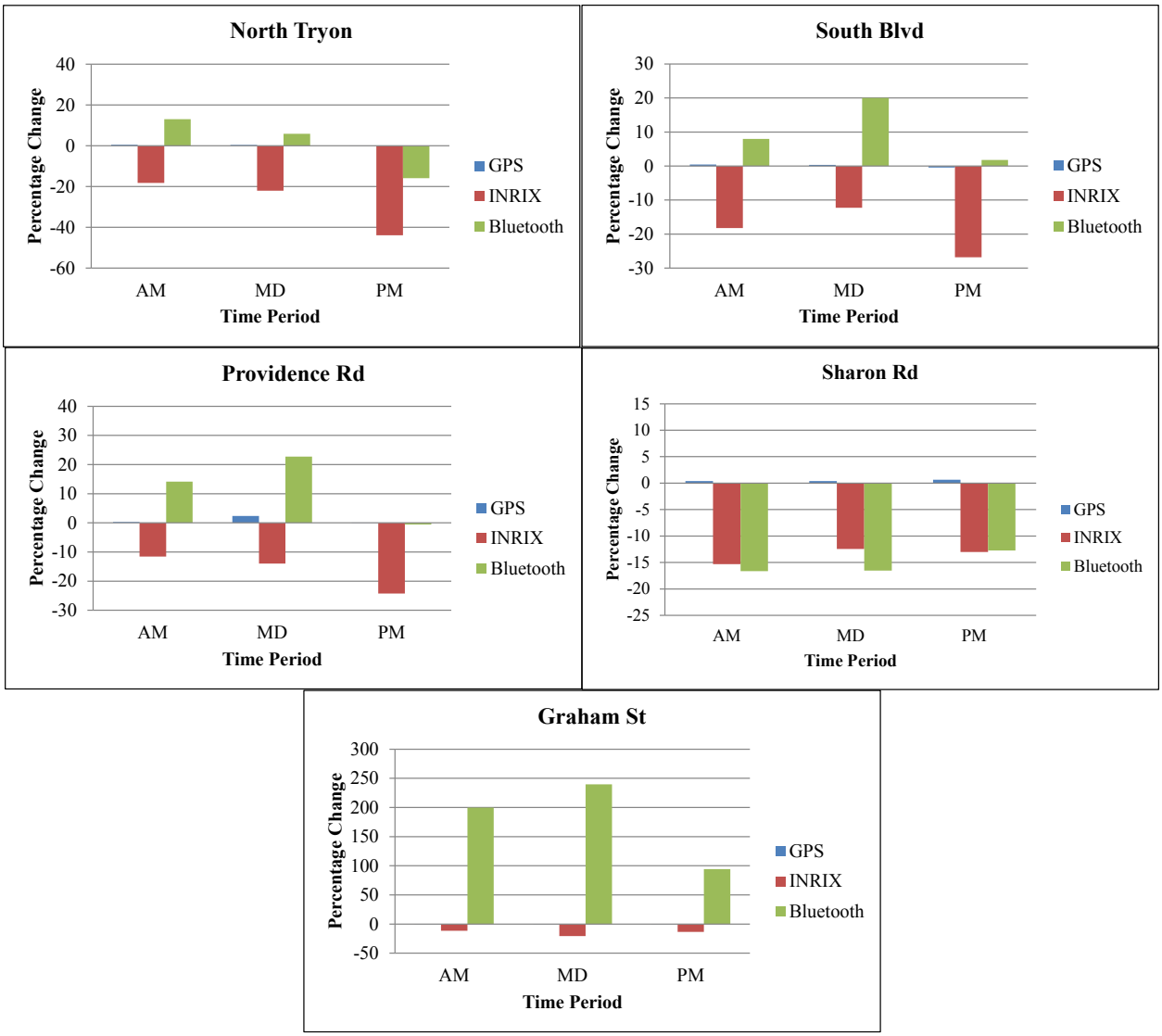


Figure 11: Percentage Difference in Travel Time by Data Collection Period

To assess and understand the reasons for the higher percentage differences, Figure 12 was generated for a section on N Graham St for the entire day. From the figure, it is evident that travel time from manual data collection (based on floating car method) is above the travel time for most of the other vehicles captured using Bluetooth detectors and INRIX. The travel time from these sources varied from a few seconds to almost 20 minutes. When most of the samples fall in 2 to 5 min category, a few of them have been spread out to higher numbers and rest of them to zero value. This leads to higher percentage difference in travel times when compared to manually collected times.

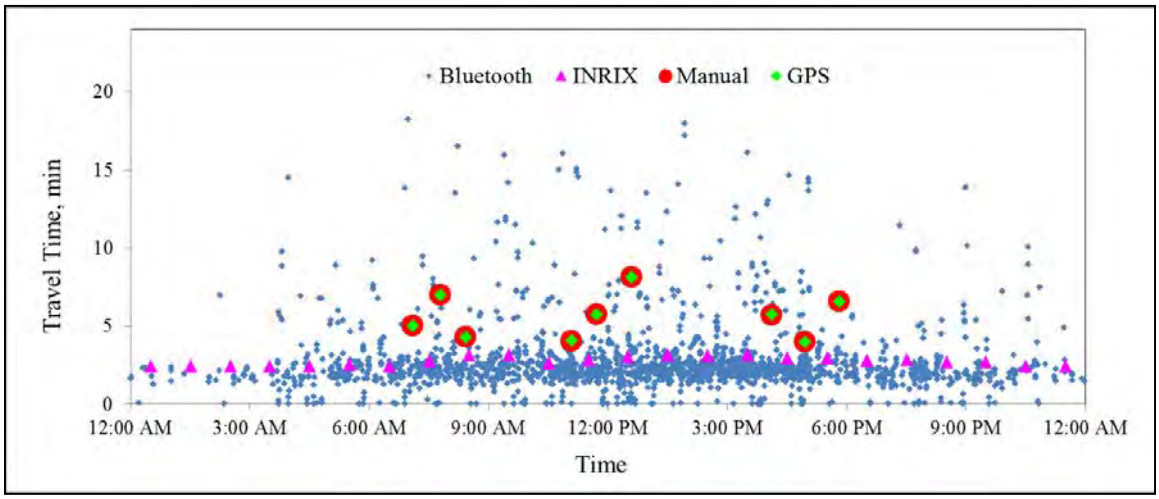


Figure 12: Travel Time Variations along the First Section of N Graham St

The aggregated travel times can therefore lead to higher travel times than the general trend line of travel times when the sample size is low. It is also clear that detections from Bluetooth detector are high and vary in travel time significantly when aggregated for the entire travel run duration. Filtering by start and end times and removing outliers from Bluetooth detector readings may give almost the same result as INRIX.

Overall, 301, 3936 and 6454 samples were detected using Acyclica filtering technique during morning, afternoon and evening peak hours (as data are captured during the entire run rather when they are detected by a detector). Table 4 and Figure 13 show the effect of detection rate or the number of travel time data samples detected and link length on travel time estimation from Bluetooth detectors. As the link length (spacing between Bluetooth detectors) increases the number of detections increased. Further, the percentage difference in travel time decreased with an increase in the link length.

Table 4: Effect of the Number of Detections from Bluetooth Detectors and Link-length / Spacing on Data Quality

South Blvd Inbound								
	Link1 (1.3 miles)		Link 2 (1.3 miles)		Link 3 (1.9 miles)		Link 4 (0.8 miles)	
	# of Detections	% Diff.	# of Detections	% Diff.	# of Detections	% Diff.	# of Detections	% Diff.
Mid-day	4	89.2	7	54.7	12	-40.1	2	-27.1
	6	77.2	2	77.4	24	-18.4	6	19.2
	4	144.4	8	98.5	12	-7.9	5	-18.4
	9	40.3	6	67.1	15	-23.4	5	-10.2
Evening	6	-12.6	4	46.4	8	-13.3	5	-50.0
	9	-12.3	1	-3.0	12	-26.8	5	-27.0
	5	-6.7	4	-5.7	6	-43.2	2	-26.2
	7	104.6	2	13.1	9	-44.3	16	0.4

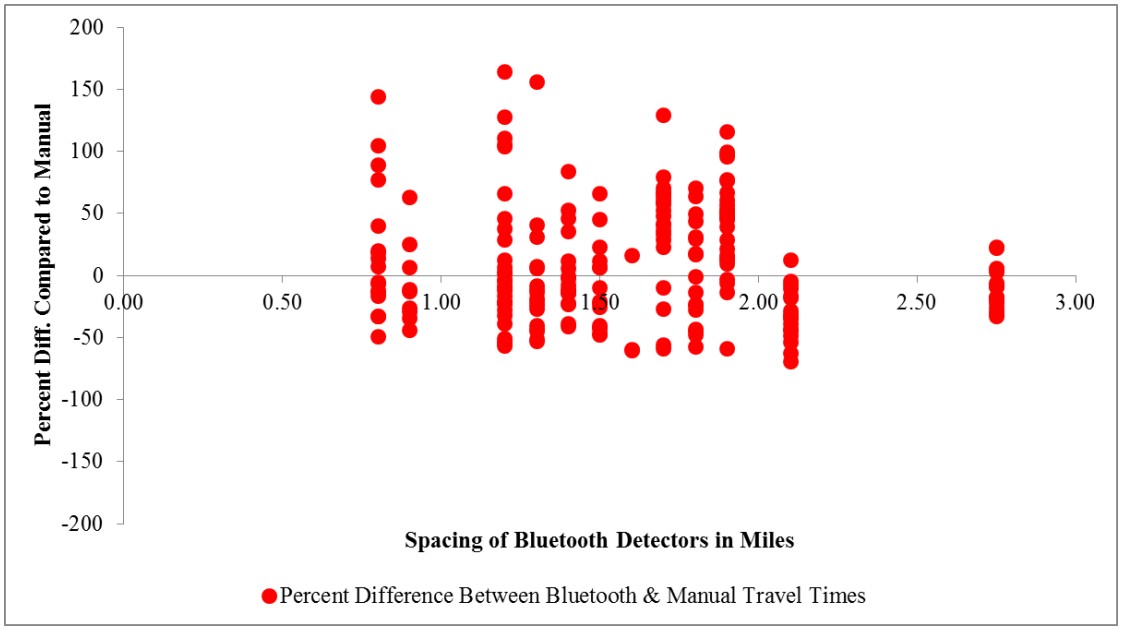


Figure 13: Relation between Bluetooth Detector Spacing and % Difference

4.1.1. Statistical Analysis Based Acyclica Filtered Bluetooth Detector Data

To compare the travel times obtained from GPS, Bluetooth detector using Acyclica filtering technique and INRIX with the benchmark (manual data), t-tests were conducted at a 95% confidence level. The Null hypothesis, H0: H*Manual* = H*GPS* = H*INRIX* = H*Bluetooth*, while the alternate hypothesis, H1: H*Manual* ≠ H*GPS*≠ H*INRIX*≠ H*Bluetooth*. The results obtained from t-tests are shown in Table 5.

From the results obtained, the zero is not between the upper and lower bound of 95% confidence Interval. This shows that the difference of the means between manual and GPS, manual and INRIX, and manual and Bluetooth detectors are statistically significant. However, unlike manual and INRIX or manual and Bluetooth detectors, the difference of means between

manual and GPS is very low (around 0.4 seconds). The correlation coefficient between manual and GPS is close to 1, which reveals that manual and GPS travel times are almost the same.

Table 5: Statistical Analyses – Results (Acyclica Filtering Technique)

For all Routes						
Paired Samples Test						
Pair	Paired Differences					Correlation
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
				Lower	Upper	
Manual - GPS	-0.44	5.05	0.17	-0.78	-0.10	1.00
Manual - INRIX	37.52	91.96	3.16	31.32	43.72	0.62
Manual - Bluetooth	-66.96	241.56	8.30	-83.24	-50.67	0.30
Arterial Routes						
Manual - GPS	-0.42	5.37	0.20	-0.81	-0.04	1.00
Manual - INRIX	43.18	96.31	3.53	36.25	50.11	0.53
Manual - Bluetooth	-75.27	256.47	9.40	-93.73	-56.81	0.20
Freeway (I-85)						
Manual - GPS	-0.53	0.99	0.10	-0.72	-0.33	1.00
Manual - INRIX	-2.96	27.29	2.68	-8.27	2.34	0.95
Manual - Bluetooth	-7.51	36.07	3.54	-14.52	-0.49	0.98

The correlation coefficient between manual and INRIX is 0.61, which reveals moderate correlation between the two travel time data samples. For manual and Bluetooth, the correlation coefficient is 0.28 (very low). Considering all the samples of arterial streets, results obtained show a statistically significant difference between the computed means. The correlation coefficient for manual and GPS data on arterial streets is 1 (high correlation), while it is 0.2 for manual and Bluetooth detectors data (very low) and 0.53 for manual and INRIX (moderate). On the other hand, the correlation coefficient is very high for manual and GPS, and, manual and INRIX data for the freeway corridor (0.90). It is reasonably high when tested by comparing manual and Bluetooth detectors data for the freeway corridor (0.77).

For interstate freeway corridor, the travel times obtained from Bluetooth are slightly better travel time estimates than those collected from INRIX as the correlation with respect to manually collected times are 0.98 and 0.95, respectively. When it comes to arterial streets, Bluetooth detectors performed with lower correlation requiring further data processing and analysis. To improve the accuracy of travel time estimation from Bluetooth detectors, a filtering technique was developed based on start and end times of the probe vehicle used for manual data collection.

4.2. Travel Time Comparison Based on Filtering Technique using Start and End Times

Micro-level analysis was done by filtering the raw data obtained from the detectors and compared to travel times collected from GPS and manual runs. Based on the start and end times of a run, filter ranges of ±1.5 min, ± 2.5 min and ± 5 min were tested to perform micro-level analysis of the raw sample from Bluetooth detectors to look at differences in travel times.

Figure 14 shows the number of samples (frequency) by percentage difference in travel times from Bluetooth detectors using various filter ranges. Out of the three filter ranges, ±1.5 min filter range yields accurate results. However, the number of detections observed was lowest for this filter range.

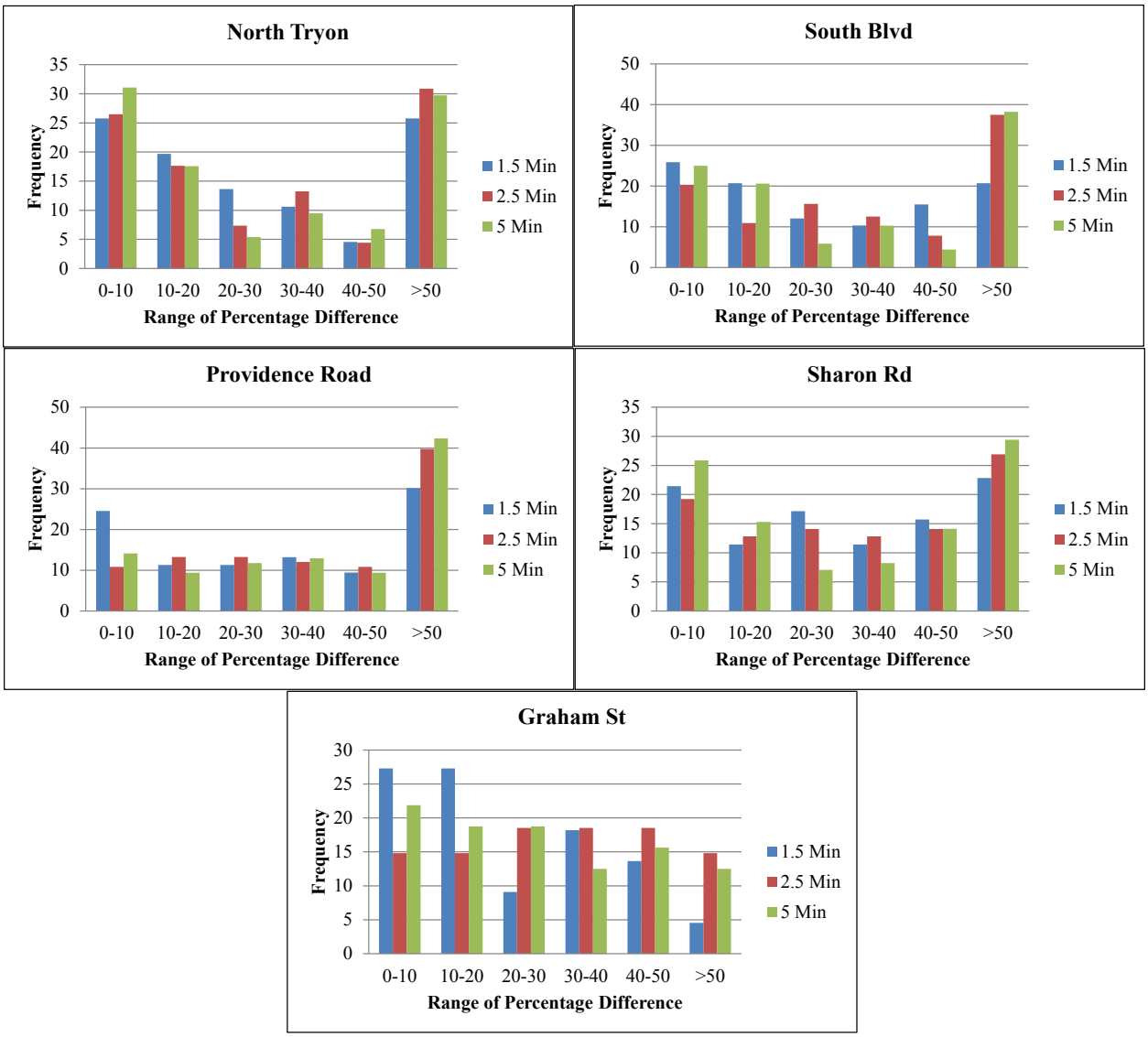


Figure 14: Percentage Difference in Travel Time from Bluetooth Detectors Using Various Filter Ranges

Based on ±1.5 min filter range, the frequency (number of samples) by percentage difference in travel times for arterial streets is shown in Figure 15. As mentioned earlier, the travel times from GPS are in the 0-10% range but the Bluetooth and INRIX travel times are widely spread in all the ranges.

For arterial streets, travel times from INRIX are relatively more accurate than Bluetooth detectors. The frequency in percentage change and periodical percentage change are higher for Bluetooth detectors than for INRIX based travel time data.

Tables 6 and 7 shows the percentage difference in travel time collected using GPS, Bluetooth detectors and INRIX compared to manual run times for both South Blvd and I-85, respectively for ±1.5 min filter range. Travel times collected from Bluetooth detectors and INRIX are observed to have high variations when compared to manual travel times. Travel times collected on I-85 are more promising when compared to travel times for arterial streets obtained from both Bluetooth detector and INRIX. For arterial streets, both Bluetooth detectors and INRIX travel

times have higher percentage differences though INRIX based travel times are better when compared to the travel time from Bluetooth detectors.

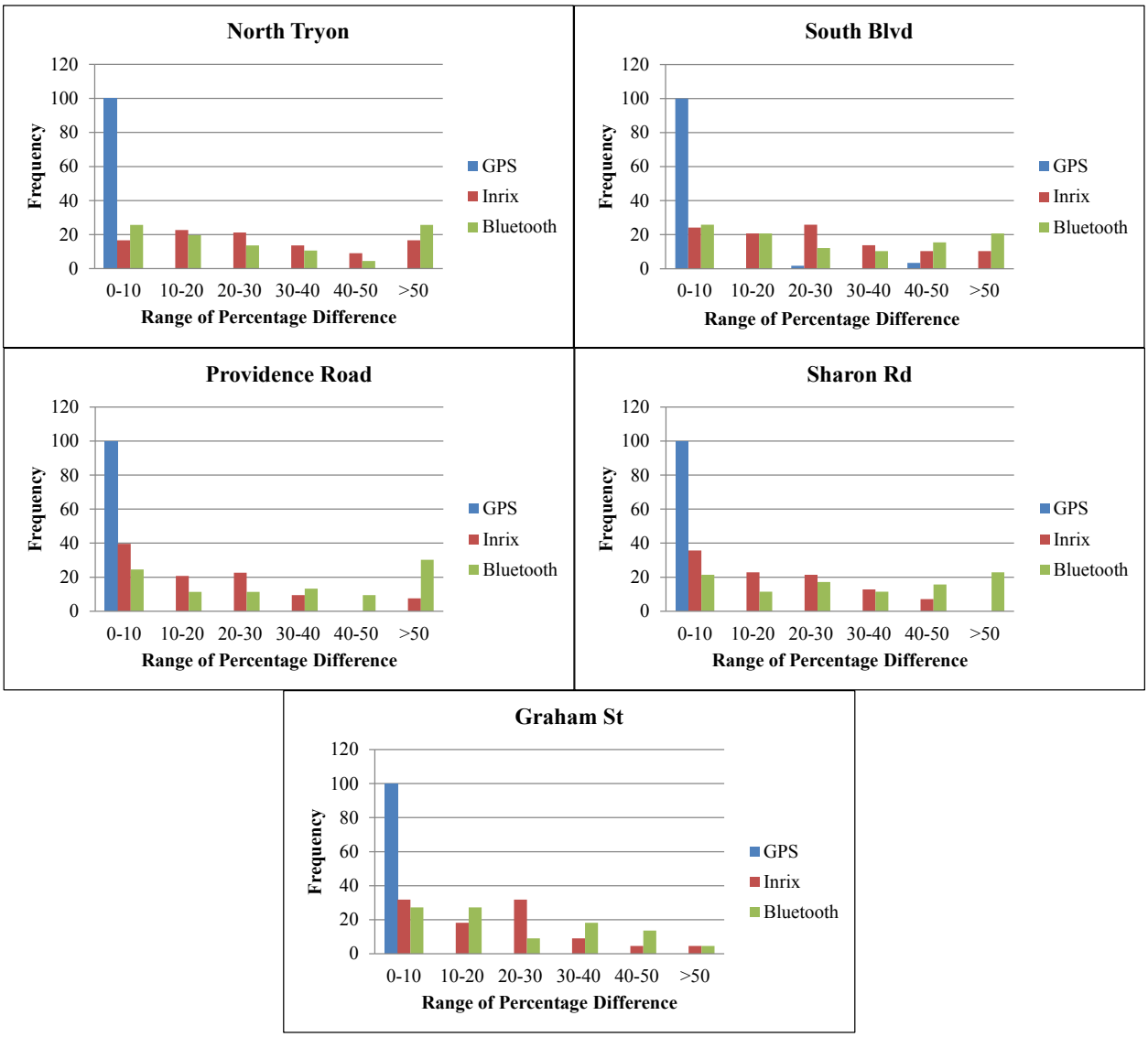


Figure 15: Percentage Difference in Travel Time from Bluetooth Detectors Using ±1.5 Min Filter Range

Table 6: Mid-day and Evening Peak Runs along South Blvd Inbound Direction

ID	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/29/2013	Run 1 (Time) 11:15 AM				Run 2 (Time) 11:49 AM				Run 3 (Time) 12:17 PM			
1	82.5	0.6	8.7	49.0	91.1	1.0	11.8	-18.3	90.0	1.1	31.3	-27.3
2	128.3	0.5	1.9	72.1	115.8	0.2	15.0	120.3	137.5	0.4	-7.1	77.7
3	323.4	0.2	-40.4	-29.5	323.8	0.1	-35.0	-22.3	246.7	0.5	-14.6	14.2
4	126.6	0.3	-24.2	7.7	123.9	0.9	-17.2	40.0	119.8	-2.3	-22.4	50.0
5/29/2013	Run 1 (Time) 4:46 PM				Run 2 (Time) 5:28 PM				Run 3 (Time) 6:20 PM			
1	150.5	16.3	-36.5	-5.3	184.0	-3.8	-49.7	1.8	173.0	1.2	-46.5	21.7
2	146.3	36.7	5.0	66.6	225.8	-0.4	-22.9	4.7	211.1	0.4	-32.4	57.1
3	244.2	-40.2	-11.1	-6.1	319.8	0.1	-46.0	-22.2	380.2	-0.1	-31.8	-28.9
4	157.9	-43.6	-16.8	-1.3	163.1	0.6	-37.1	-0.7	146.5	0.3	-50.9	-5.0

Table 7: Mid-day and Evening Peak Runs along I-85 Inbound Direction

ID	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/25/2013	Run 1 (Time) 11:03 AM				Run 2 (Time) 11:28 AM				Run 3 (Time) 11:51 PM			
1	91.2	-0.2	28.1	-2.0	91.5	-1.6	114.4	-2.7	91.7	-0.8	28.0	16.2
2	92.6	-0.6	-7.6	-34.1	92.6	0.4	-57.9	-27.1	91.2	-0.2	-8.6	-45.0
3	48.6	-1.2	-17.3	11.0	48.7	-3.5	-19.9	5.3	50.6	-1.2	-20.6	4.9
4	104.3	-0.3	-14.9	-24.0	102.3	-0.3	-15.0	-22.3	105.4	-0.4	-16.9	-30.6
6/25/2013	Run 1 (Time) 4:07 PM				Run 2 (Time) 4:33 PM				Run 3 (Time) 5:13 PM			
1	90.7	0.3	-0.1	21.0	90.8	0.2	29.3	12.9	90.1	1.0	30.3	--
2	94.1	1.0	-10.1	-29.3	90.3	-0.3	-5.6	-43.2	81.4	2.0	4.7	-18.0
3	53.4	3.0	-27.0	0.1	49.3	-0.6	-19.7	12.7	50.1	1.8	-22.2	-6.0
4	104.5	-1.4	-15.0	-32.7	102.3	-1.3	-12.6	-33.2	103.6	-0.6	-15.6	-28.7

Table 8 shows the effect of the number of detections and link length on data quality for different filter ranges. Travel times from ±1.5 min filter ranges have lower sample size but the percentage differences are lower when compared to other filter ranges.

Table 9 shows the sample sizes based on time-of-the-day. For INRIX, the sample sizes shown are not the actual counts but are equivalent to the manual runs. In the case of Bluetooth detectors, the sample sizes are based on the number of detections summed up for all the links. The number of detections from Bluetooth detectors is lower during the morning peak hours and higher during mid-day and evening peak hours. This may be because of higher noise levels / disturbance, weather and environmental conditions, placement location of Bluetooth detectors, or varying traffic volumes during different time periods.

Table 8: Effect of the Number of Detections from Bluetooth Detectors and Link-length / Spacing on Data Quality for Various Filter Ranges

South Blvd – Inbound Direction Evening Peak									
Filter Ranges	Run	Link1 (1.3 miles)		Link 2 (1.3 miles)		Link 3 (1.9 miles)		Link 4 (0.8 miles)	
		# of Detections	% Diff.	# of Detections	% Diff.	# of Detections	% Diff.	# of Detections	% Diff.
±1.5 Min	1	5	-12.6	4	46.4	8	-13.3	7	-50
	2	10	-12.3	3	-3	11	-26.8	6	-27
	3	5	-6.7	7	-5.7	6	-43.2	5	-26.2
	4	6	104.6	2	13.1	9	-44.3	19	0.4
±2.5 Min	1	5	96.1	5	42.4	11	16.7	8	-10.5
	2	11	-32.9	4	94	13	22.1	7	-22.4
	3	5	-48.8	8	21.4	11	-60.4	5	-66.9
	4	6	11.8	4	51.7	12	62	21	335.9
±5 Min	1	15	-12.5	7	46.4	18	4.6	19	-58.7
	2	16	7.3	8	44.2	16	-18.6	12	-42.7
	3	12	54.9	12	12.4	13	-30.4	9	18.8
	4	10	177.1	6	13.1	27	-40.8	26	31.7

Table 9: Sample Size by Time-of-the-day

Sample Sizes for Arterial Roads				
Technology/Source		AM Peak	Mid-day	PM Peak
Manual/GPS		332	140	296
INRIX		332	140	296
Bluetooth (# of Detections)	Acyclica filtering (total during the travel runs)	301	3,936	6,454
	±1.5 Min Filter	63	704	1,222
	±2.5 Min Filter	83	933	1,550
	±5.0 Min Filter	122	1,458	2,426

The number of detections based on time-of-the-day for the arterial streets are compiled together to examine which corridors have better results and what might be the reason for variation in the number of detections from Bluetooth detectors. Figure 16 shows the number of detections during each hour using Bluetooth detectors on arterial streets. The number of detections during the morning peak period is lower than those compared to other time periods.

Corridors pertaining to bus route 12 and 20 have better results compared to other routes. The number of detections from all the other corridors is on the lower side when compared to corridors pertaining to bus routes 12 and 20. Table 10 and Figure 17 show the number of detections based on time periods on arterial streets. As the filter range increases the number of detections tends to increase. As the day progresses the number of detections have also increased.

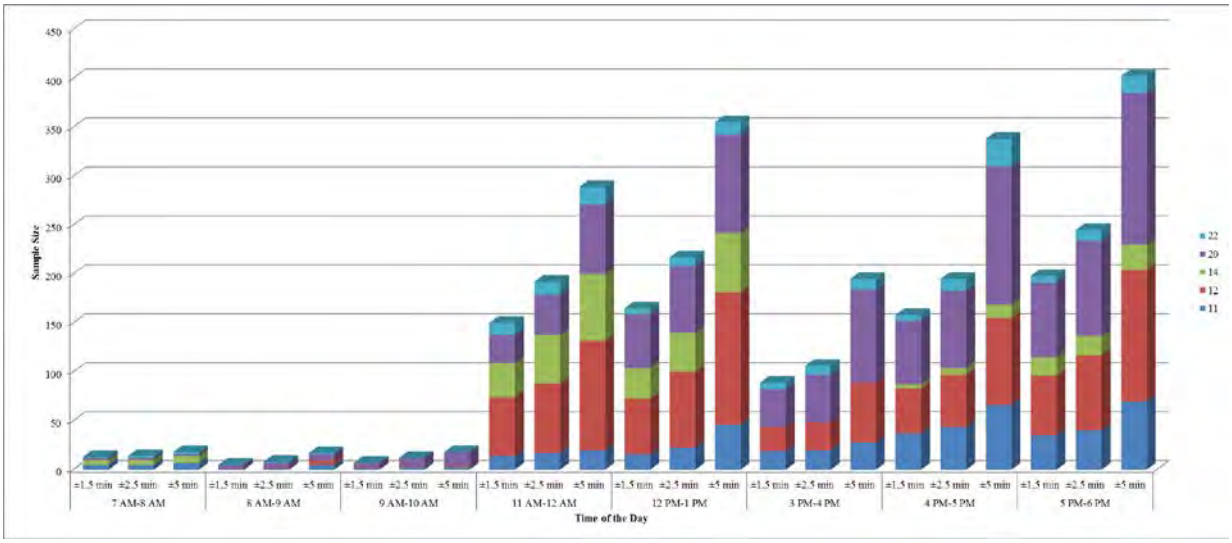


Figure 3: Number of Detections During Each Hour from Bluetooth Detectors

Table 10: Number of Detections Based on Time Period for Arterial Streets

Bus Route	AM Peak (7 AM-10 AM)			Mid-Day (11 AM-1 PM)			PM Peak (3 PM-6 PM)		
	±1.5 min	±2.5 min	±5 min	±1.5 min	±2.5 min	±5 min	±1.5 min	±2.5 min	±5 min
11	6	9	15	30	40	66	91	104	164
12	1	2	7	117	148	247	132	158	284
14	5	5	7	66	90	129	23	27	40
20	12	15	21	84	109	171	179	225	391
22	1	3	3	18	22	31	20	32	56
All	25	34	53	315	409	644	445	546	935

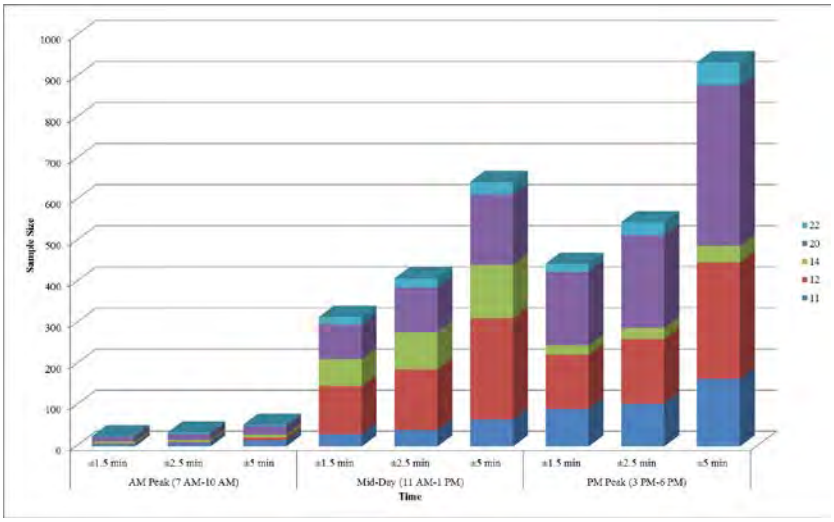


Figure 17: Number of Detections Based on Time Period for Arterial Streets

Figure 18 shows the effect of spacing of Bluetooth detectors on data quality for different filter ranges. The percentage difference in travel times from Bluetooth detectors compared to manual is lower in case of ±1.5 min filter range when compared to ±2.5 min and ±5 min filter ranges. Also, the percentage difference tends to decrease with an increase in link length for ±1.5 min, ±2.5 min and ±5 min filter ranges. To evaluate the effect of Bluetooth detector spacing on data quality, a correlation between difference in travel times from each filter range and spacing between the Bluetooth detectors was examined (Table 11). From Table 11, travel time difference from all the three filter ranges are negatively correlated (with ±2.5 min filter range at 95% confidence and ±5 min filter range at 99% confidence interval) to the spacing between Bluetooth detectors. The observed negatively correlated values indicate that the quality of the data from Bluetooth detectors improves as the spacing between the Bluetooth detectors increase.

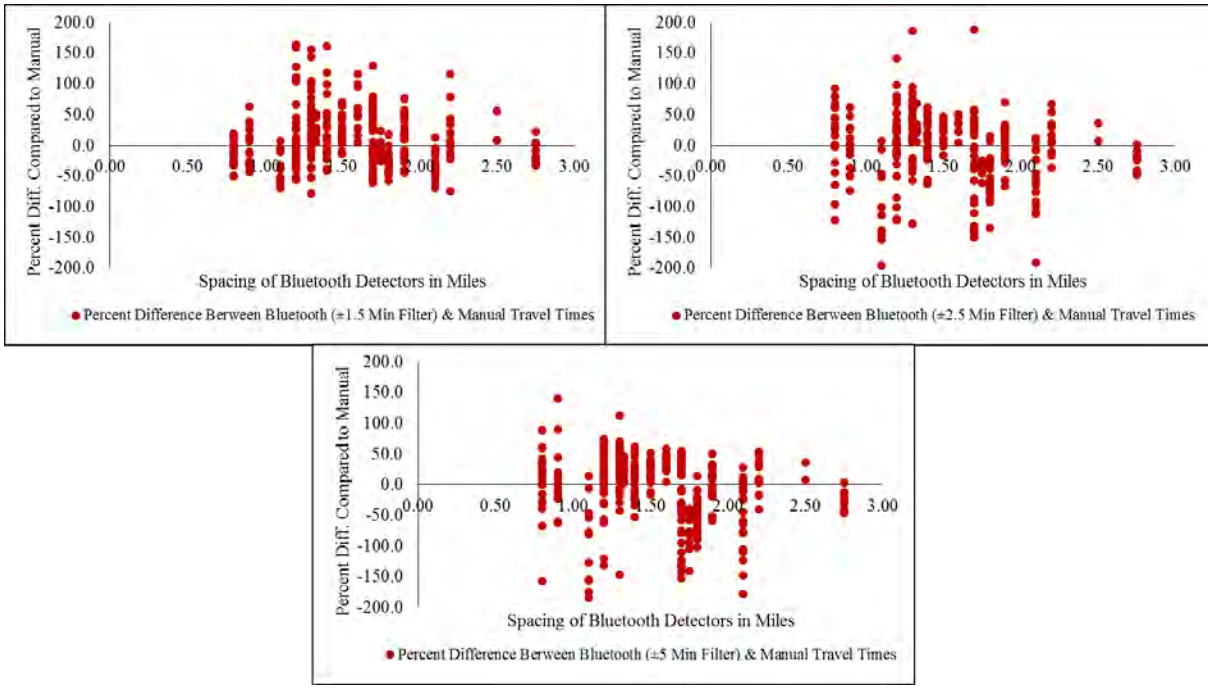


Figure 18: Relation between Bluetooth Detector Spacing and Percent Difference for Various Filter Ranges

The location of signal cabinet controller (in which the Bluetooth detector is placed) could have a bearing on the number of detections by direction or time period. As an example, one may expect to detect more number of samples (due to close proximity of the Bluetooth detector to the approach) in the inbound direction (more traffic toward uptown or downtown) during the morning peak period if the signal cabinet controller is on the inbound side of an intersection. Likewise, if the signal cabinet controller is on the outbound (away from uptown or downtown) side of the intersection, one may expect to detect more number of samples during the evening peak hours. To examine if the location of signal cabinet controller had a bearing on the number of samples captured during different time periods, the location of signal cabinet controller and its distance from the center of the intersection were extracted and summarized in Table 12. Comparing Table 12 with percentage differences in travel times, it can be stated that signal cabinet controller location does not seem to have a bearing on the number of samples captured (detection rate). As an example, all signal cabinet controllers are located towards inbound

direction of the selected intersections along corridor pertaining to bus route 14. However, the number of samples detected during morning peak periods along this corridor is still very low (Table 10).

Table 11: Correlation between Travel Times from Bluetooth Detectors and Spacing

	Section Length (Spacing Between Bluetooth Detectors)		
	Pearson Correlation Coefficient	Significance	N
±1.5 Min Filter	-0.056	0.33	308
±2.5 Min Filter	-0.12*	0.04	302
±5 Min Filter	-0.142**	<0.01	342

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 12: Location of Bluetooth Detectors - Summary

Bus Route	Link	Intersection	Signal Cabinet (Inbound/Outbound)	Distance to the center of Road (Feet)
11	1	N Tryon St & E WT Harris Blvd	Outbound	133.5
11	2	N Tryon St & I-85 Connector / Sandy Ave	Inbound	147.2
11	3	N Tryon St & Old Concord Rd	Outbound	45.1
11	4	N Tryon St & E Sugarcreek Rd	Outbound	82.2
11	5	N Tryon & Matheson Ave / W 30th	Outbound	59.5
12	1	South Blvd & E Woodlawn Rd	Inbound	83.5
12	2	South Blvd & Tyvola Rd	Outbound	81.1
12	3	South Blvd & Arrowood / Starbrook	Inbound	44.1
12	4	South Blvd & Sharon Rd	Outbound	58.9
14	1	Providence Rd & Pineville-Matthews Rd	Inbound	68.3
14	2	Providence Rd & Alexander Rd/Rea Rd	Inbound	83.7
14	3	Providence Rd & Sardis Rd / Fairview Rd	Inbound	64.2
14	4	Providence Rd & Sharon Amity Rd / Sharon Rd	Inbound	46.6
20	1	Park Rd & Birnen Dr / Johnson Rd	Outbound	38.1
20	2	Park Rd & Sharon Rd W/Gleneagles	Inbound	51.1
20	3	Sharon Rd & Quail Hollow Rd	Outbound	51.1
20	4	Sharon Rd & Fairview Rd	Outbound	96.7
20	5	Sharon Rd & Wendover Rd	Inbound	64.4
22	1	Mallard Creek Rd & W WT Harris	Outbound	108.1
22	2	W Sugar Creek & N Graham St / Mineral	Outbound	49.3
22	3	N Graham St & N I-85 Service Rd	Outbound	66.1
22	4	N Graham St & Norris Ave	Outbound	72.8
			Average =	72.5

4.2.1. Statistical Analysis Based on Filtering Technique using Start and End Times

To compare the travel times obtained from GPS, Bluetooth based on filtering technique using start and end times and INRIX with the benchmark (manual data), t-tests were conducted at a 95% confidence level. The Null hypothesis, H0: H*Manual* = H*GPS* = H*INRIX* = H*Bluetooth*, while the alternate hypothesis, H1: H*Manual* ≠ H*GPS*≠ H*INRIX*≠ H*Bluetooth*. The results obtained from t-tests are shown in Table 13.

From the results obtained, the zero is not between the upper and lower bound of 95% confidence interval. This shows that the difference of the means between manual and Bluetooth detectors based on filtering technique using start and end times are statistically significant. From the results shown in Table 4 and Table 13, one can infer that by using this filtering technique the mean, standard deviation and the standard error mean have reduced significantly. This shows that the proposed method can be used to filter Bluetooth data and obtain relatively accurate estimates. The correlation between manual and Bluetooth travel times has increased to 0.49 by using this technique. Out of the three filter ranges used, ±1.5 min filter range gave better results.

Table 13: Statistical analyses of Travel Times Obtained by using 1.5 Min Filter range

Paired Samples Test						
Pair	Paired Differences					Correlation
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		
				Lower	Upper	
Arterial Streets and Freeways Combined Together						
Manual - Bluetooth	17.33	107.41	6.20	5.13	29.54	0.49
Arterial Street Corridors						
Manual - Bluetooth	15.35	113.08	7.86	0.14	30.85	0.23

4.6. Role of On-network Characteristics

On-network characteristics such as speed limit, the number of signalized and unsignalized intersections, the number of turnings, the number of bus stops, vehicular volume and the direction of travel as well as time-of-the-day (AM peak, mid-day or PM peak) play an important role in variation of travel times. The on-network characteristics were collected for all the sections along each study corridor through field visits. Since, each section is different from other in length, relevant on-network characteristics and variations of travel times were computed per unit length by dividing them with the respective section length. Statistical analysis was conducted to examine the role of on-network characteristics in travel time and the difference in travel time collected manually and using GPS, Bluetooth detectors and INRIX.

After compiling all the data, scatter plots were generated (Figure 19) so as to analyze the data for normality and to remove any outliers that would affect the output of the model. Travel times from all the sources were plotted and the outliers were removed from the data. The travel times plotted in Figure 19 are the average travel times for each section for different time periods on different corridors.

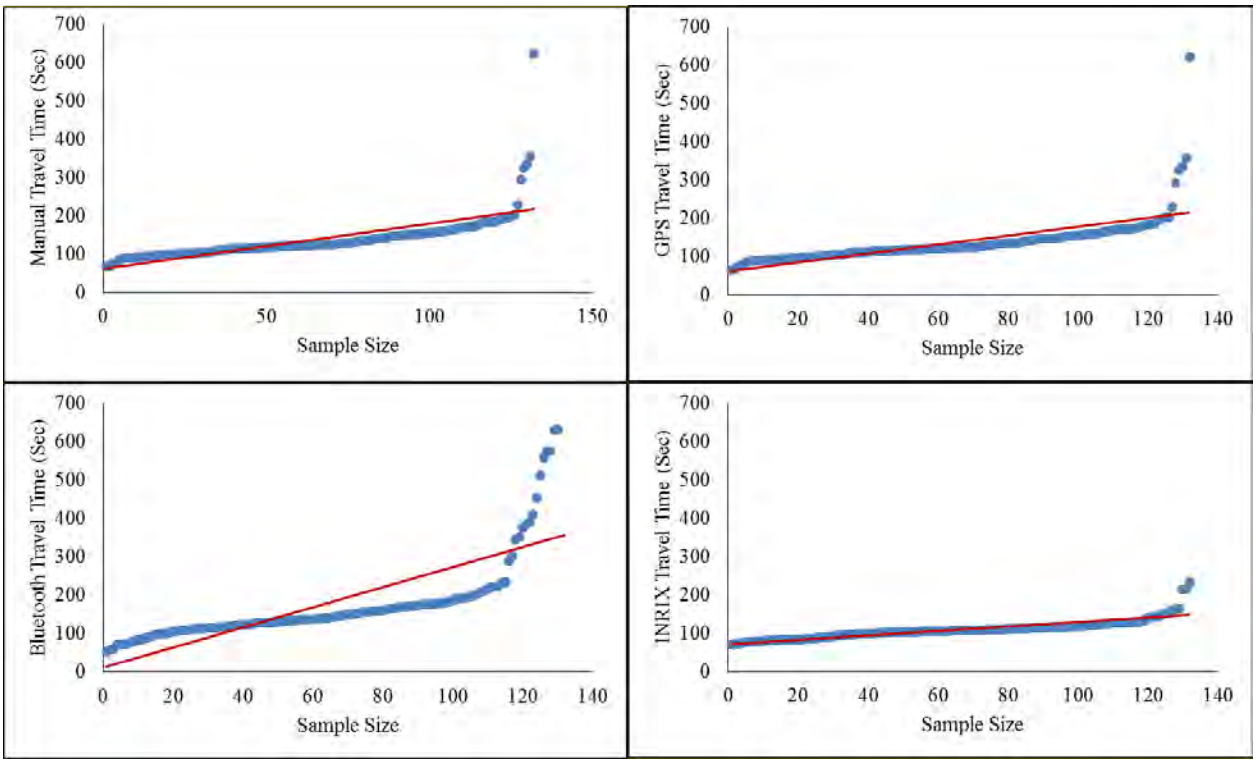


Figure 19: Scatter Plots for Travel Times Obtained from Various Sources

Table 14 shows the Pearson correlation coefficients between travel times from various sources and all the aforementioned characteristics. From Table 14, the higher Pearson correlation coefficient for the number of signalized intersection in the case of travel times from both Bluetooth detectors and INRIX indicate that the presence of signalized intersections along the study corridor plays a statistically significant role in the travel times estimated from Bluetooth detectors and INRIX data (possibly due to signal phasing patterns, timing patterns and delay). Similarly, the number of residential driveways per mile and total number of turnings per mile play a statistically significant role in travel times estimated from INRIX.

Since variations were observed between the travel times collected from various sources, Pearson correlation coefficients were computed to evaluate the role of on-network characteristics in the travel time difference observed. Table 15 shows Pearson correlation coefficients between the percent difference in manual travel times and travel times from GPS, Bluetooth detectors and INRIX, and on-network characteristics. From Table 15, the percent difference between manual and Bluetooth travel times per mile is highly correlated with the number of residential driveways per mile, the number of lanes and traffic volume at a 95% confidence level. This indicates that an increase in the number of residential driveways per mile, the number of lanes and traffic volume will have a significant effect on percent difference between manual and Bluetooth travel times. Similarly, the percent difference between manual and INRIX travel times per mile is highly correlated with the number of residential driveways per mile, the number of turnings per mile, the number of lanes, traffic volume and PM peak period at a 95% confidence level. This indicates that an increase in the number of residential driveways per mile, the number of turnings per mile, the number of lanes, traffic volume and PM peak period leads to a higher percent difference between manual and INRIX travel times.

Table 14: Correlation between Travel Times from Various Sources and the Variables

	Manual Travel Time per Mile	GPS Travel Time Per Mile	Bluetooth Travel Time per Mile	INRIX Travel Time per Mile
Manual Travel Time per Mile	1			
GPS Travel Time Per Mile	.998**	1		
Bluetooth Travel Time per Mile	0.08	0.083	1	
INRIX Travel Time per Mile	.679**	.692**	-0.015	1
Inbound	0.064	0.062	-0.01	0.112
Outbound	-0.064	-0.062	0.01	-0.112
Speed Limit (35mph)	0.036	0.034	.215*	0.074
Speed Limit (45 mph)	-0.036	-0.034	-.215*	-0.074
# of Signalized Intersections per Mile	.314**	.309**	.237*	.234*
# of Unsignalized Intersections per Mile	0.068	0.065	-0.083	0.149
# of Commercial Driveways per Mile	0.123	0.119	0.164	0.004
# of Residential Driveways per Mile	0.097	0.106	-.207*	.470**
# of Turnings per Mile	0.101	0.114	-0.014	.467**
# of Busstops per Mile	0.056	0.052	0.157	-0.146
# of Lanes	-0.081	-0.071	-.219*	0.018
Traffic Volume	0.044	0.031	-0.176	-0.075
AM Peak Period	-0.123	-0.118	-0.022	-0.079
Mid-day Period	-0.007	-0.003	0.07	0.01
PM Peak Period	0.132	0.122	-0.047	0.07

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 15: Correlation between Percent Difference in Manual Travel Time and Travel Times from Various Sources and the Variables

	Percent Diff. between Manual and GPS Travel Time per Mile	Percent Diff. between Manual and Bluetooth Travel Time per Mile	Percent Diff. between Manual and INRIX Travel Time per Mile
Inbound	0.042	0.018	-0.007
Outbound	-0.042	-0.018	0.007
Speed Limit (35mph)	0.02	-0.174	-0.014
Speed Limit (45 mph)	-0.02	0.174	0.014
# of Signalized Intersections per Mile	0.087	-0.155	0.081
# of Unsignalized Intersections per Mile	0.102	0.119	0.024
# of Commercial Driveways per Mile	0.052	-0.106	0.16
# of Residential Driveways per Mile	-0.098	.252*	-.206*
# of Turnings per Mile	-0.157	0.053	-.221*
# of Busstops per Mile	0.062	-0.123	0.193
# of Lanes	-0.184	.197*	-.199*
Traffic Volume	.200*	.200*	.217*
AM Peak Period	-0.109	0	-0.114
Mid-day Period	-0.038	-0.102	-0.09
PM Peak Period	0.149	0.101	.205*

*. Correlation is significant at the 0.05 level (2-tailed).

CHAPTER 5: CONCLUSIONS

This report presents an analysis and evaluation of the quality and accuracy of travel times obtained from GPS unit, Bluetooth detectors, and INRIX by comparing it with manual data (ground truth). The travel time data from both Bluetooth detectors and INRIX are reasonably close to manually captured travel time data along the interstate freeway corridor than when compared to arterial street corridors. For arterial streets, travel times from INRIX are more promising when compared to the travel times from the Bluetooth detectors. The Bluetooth detectors showed more samples in higher percentage difference (for most time periods considered) than INRIX. These findings are supported by t-tests conducted at a 95% confidence level.

Based on the start and end times of the run, filter ranges of ±1.5 min, ± 2.5 min and ± 5 min were tested to perform micro-level analysis of the raw sample from Bluetooth detectors and compute percentage differences in travel times. Out of the three filter ranges, ±1.5 min filter range yielded accurate results but lowest number of detections. The travel times from INRIX, however, are more promising than those obtained from Bluetooth detectors even after filtering data using the proposed method (based on minimum and maximum travel time for each section).

The reasons for the difference in travel time for both arterial streets and freeway using Bluetooth detectors and INRIX could be the source of data, outliers, and on-network characteristics. The relationship between spacing of locations at which data are captured using Bluetooth detectors indicate that as the spacing between the Bluetooth detectors increases the percentage difference in travel time decreases. Similarly, the percentage differences are observed to be lower when the numbers of detections are higher.

Overall, it can be concluded that Bluetooth detectors and INRIX are promising methods to capture travel times on freeways. However, for arterial streets, INRIX is found to be a better data source to extract travel time than when compared to Bluetooth detectors at the time of this study.

Time-of-the-day seem to play a role in the number of samples captured (detection rate) using Bluetooth detectors. This could be partly attributed to traffic conditions, while environmental conditions could be other associated factor. Increased usage of Bluetooth enabled devices and technological advancements may lead to improved capture of detections and data quality using Bluetooth detectors in the future.

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APPENDIX

Table A-1: Percentage Difference in Travel Times on N Graham St, Inbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/21/2013	7 AM - 9 AM	Run 1 (Time) 06:55:00				Run 2 (Time) 07:30:00				Run 3 (Time) 08:14:00							
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	320.80	-0.56	-38.22	82.39	527.70	-1.08	-63.40	-4.40	382.30	-0.86	-49.25	88.56				
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	195.50	2.81	-35.24	-0.55	164.40	3.41	-21.17	97.09	219.40	1.19	-37.92	76.55				
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	202.40	-2.67	-7.21	88.09	172.70	-0.98	-3.42	-6.87	185.20	-0.11	12.10	-3.55				
N Graham St & Norris Ave	N Graham St & Dalton Ave	143.60	0.97	-12.26	1200.25	238.40	0.67	-38.34	327.18	180.70	0.17	-19.31	19.53				
5/21/2013	11 AM - 1 PM	Run 1 (Time) 10:57:00				Run 2 (Time) 11:35:00				Run 3 (Time) 12:15:00							
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	282.30	-0.46	-31.70	321.47	288.90	-0.66	-32.68	316.44	278.50	0.18	-33.79	419.77				
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	124.80	0.96	4.33	69.95	167.40	0.96	-20.43	96.41	163.00	-0.61	-20.90	137.63	Not available			
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	162.00	0.00	-2.22	463.30	156.50	0.32	13.10	632.83	243.90	-0.37	-29.64	373.26				
N Graham St & Norris Ave	N Graham St & Dalton Ave	168.50	-0.30	-23.09	382.26	156.70	0.19	7.59	426.40	146.90	0.75	-11.78	461.52				
5/21/2013	4 PM - 6 PM	Run 1 (Time) 03:56:00				Run 2 (Time) 04:35:00				Run 3 (Time) 05:17:30							
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	268.80	-1.04	-21.80	473.38	285.00	1.40	-26.25	440.79	304.90	-0.95	-16.10	430.82				
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	112.00	1.79	20.54	117.32	160.80	0.12	-14.18	269.24	142.60	1.68	0.14	146.79				
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	183.00	-1.64	5.90	86.45	159.70	0.19	50.66	50.53	222.60	0.18	-20.49	16.94				
N Graham St & Norris Ave	N Graham St & Dalton Ave	153.50	0.98	-13.22	305.31	132.40	-0.30	0.60	367.06	202.70	1.13	-36.06	23.04				
5/22/2013	7 AM - 10 AM	Run 1 (Time) 06:58:00				Run 2 (Time) 07:35:00				Run 3 (Time) 08:30:00				Run 4 (Time) 09:14:00			
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	289.80	-0.97	-30.99	329.30	436.90	-0.43	-55.64	183.74	580.00	-0.69	-65.52	103.03	266.50	-0.56	-25.40	411.12
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	128.10	1.48	1.64	121.51	133.60	1.80	-2.54	133.83	149.70	0.87	-5.01	54.78	117.10	1.62	18.36	280.15
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	191.80	-1.46	-13.03	4.52	192.10	-0.05	4.32	61.86	178.90	-0.50	12.02	10.37	215.50	-0.23	-10.07	157.04
N Graham St & Norris Ave	N Graham St & Dalton Ave	142.20	-0.14	-8.86	924.21	186.70	0.16	-36.05	626.00	181.30	0.39	-26.53	256.93	223.30	0.76	-34.71	201.67
5/22/2013	7 AM - 10 AM	Run 1 (Time) 02:59:00				Run 2 (Time) 03:44:20				Run 3 (Time) 04:30:20				Run 4 (Time) 05:24:20			
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	310.80	-0.90	-33.91	264.06	293.90	-0.65	-30.11	381.61	324.70	-0.22	-38.47	357.84	356.90	-0.81	-45.70	279.46
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	149.70	2.20	-17.43	125.64	198.10	1.97	-27.31	153.31	116.80	1.03	18.15	138.23	145.50	1.72	-3.09	162.93
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	221.80	-0.36	-12.62	76.01	241.90	-0.79	-22.36	47.60	232.90	0.47	-13.95	51.35	177.30	-0.17	-8.29	110.11
N Graham St & Norris Ave	N Graham St & Dalton Ave	138.00	0.00	-8.70	226.74	130.30	0.54	73.60	120.55	158.70	0.19	-16.07	70.01	168.90	0.65	-25.40	49.17

Table A-2: Percentage Difference in Travel Times on N Graham St, Outbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/21/2013	7 AM - 9 AM	Run 1 (Time) 7:13:00				Run 2 (Time) 7:53:00				Run 3 (Time) 8:36:00							
N Graham St & Dalton Ave	N Graham St & Norris Ave	160.40	-0.25	-15.09	354.59	174.70	0.17	-22.04	157.99	160.00	0.63	-28.00	112.14				
N Graham St & Norris Ave	N Graham St &N I-85 Service Rd	166.50	0.30	9.19	1.68	165.80	0.12	13.27	48.31	173.90	0.63	19.03	41.40				
N Graham St &N I-85 Service Rd	W Sugar Creek& N Graham/Mineral	170.60	0.82	-15.24	218.05	269.90	0.78	-44.20	83.36	246.00	-1.22	-29.27	224.76				
W Sugar Creek& N Graham/Mineral	Mallard Creek Rd & W WT Harris	290.70	0.45	-11.32	478.32	299.10	-0.70	-12.00	134.16	284.10	-0.04	-2.50	7.94				
5/21/2013	11 AM - 1 PM	Run 1 (Time) 11:14:00				Run 2 (Time) 11:56:00				Run 3 (Time) 12:39:00							
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	168.90	-1.12	-27.89	470.07	154.00	1.95	-14.29	448.58	160.10	0.56	-17.55	493.87				
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	250.60	0.96	-29.37	149.67	327.00	0.61	-45.87	88.57	214.30	-0.61	-3.41	400.28	Not available			
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	174.80	0.69	-20.37	93.93	201.90	0.05	-31.35	263.08	175.80	0.68	-15.02	164.27				
N Graham St & Norris Ave	N Graham St & Dalton Ave	329.50	-0.15	-18.85	153.21	269.90	-0.33	-3.30	205.59	295.70	1.12	-11.19	232.55				
5/21/2013	4 PM - 6 PM	Run 1 (Time) 04:15:00				Run 2 (Time) 04:55:00				Run 3 (Time) 5:52:30							
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	132.20	-1.66	47.96	745.22	149.20	0.54	-30.03	561.66	149.60	0.94	-25.00	559.90				
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	163.80	0.73	41.03	50.67	169.90	1.82	31.02	16.60	150.10	-0.07	37.91	35.70				
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	176.70	0.17	-13.62	67.41	178.70	-1.51	-13.04	232.94	214.80	-0.37	-31.84	117.53				
N Graham St & Norris Ave	N Graham St & Dalton Ave	461.00	0.87	-38.09	43.17	451.80	0.27	-26.96	-22.76	483.60	0.50	-41.19	-48.43				
5/22/2013	7 AM - 10 AM	Run 1 (Time) 07:18:00				Run 2 (Time) 08:08:00				Run 3 (Time) 08:54:00				Run 4 (Time) 09:32:00			
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	142.00	0.00	-4.08	250.18	119.40	-1.17	14.07	259.80	160.90	-0.56	-22.44	42.82	126.20	0.63	4.60	265.97
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	163.50	0.92	26.61	153.27	225.80	0.09	-4.87	20.59	250.80	1.28	-22.73	33.60	235.40	0.25	-17.67	302.48
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	191.80	0.63	-27.42	209.93	255.20	0.31	-37.93	515.01	154.40	-0.91	-2.85	446.05	161.00	-1.24	-4.22	225.38
N Graham St & Norris Ave	N Graham St & Dalton Ave	300.30	0.23	-18.08	364.80	303.50	-0.49	-12.69	311.10	295.00	-0.34	-7.53	76.09	258.20	1.08	4.14	178.50
5/22/2013	3 PM - 6 PM	Run 1 (Time) 03:26:30				Run 2 (Time) 04:05:30				Run 3 (Time) 04:49:40				Run 4 (Time) 05:47:10			
Mallard Creek Rd & W WT Harris	W Sugar Creek& N Graham/Mineral	171.80	-0.47	-18.28	430.32	171.50	0.29	-30.83	279.65	324.70	-0.52	-61.56	-19.59	132.70	0.98	-0.12	21.35
W Sugar Creek& N Graham/Mineral	N Graham St &N I-85 Service Rd	212.40	0.75	34.75	18.92	162.50	1.54	-18.40	43.45	116.80	1.03	90.58	66.10	147.40	1.76	40.43	38.58
N Graham St &N I-85 Service Rd	N Graham St & Norris Ave	183.10	0.49	-22.67	463.45	202.90	0.05	-19.57	173.14	232.90	0.04	-36.11	121.40	181.00	0.00	9.72	96.33
N Graham St & Norris Ave	N Graham St & Dalton Ave	331.50	-0.15	-13.54	-2.94	421.70	0.07	-31.89	-31.85	158.70	0.19	108.95	58.76	544.70	0.24	-38.09	-55.95

Table A-3: Percentage Difference in Travel Times on N Tryon St, Inbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/5/2013	7 AM- 9 AM	Run 1 (Time) 7:00:8				Run 2 (Time) 7:38:45				Run 3 (Time) 8:29:12							
N Tryon St & E WT Harris Blvd	N Tryon St & I-85 Conn/Sandy Ave	300.60	0.13	-51.86	-56.35	420.20	-0.29	-62.02	-64.56	256.10	0.35	-15.78	-35.11				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & Old Concord Rd	131.80	3.19	17.37	157.95	136.90	7.38	10.30	116.11	177.80	0.67	-12.94	61.83				
N Tryon St & Old Concord Rd	N Tryon St & E Sugarcreek Rd	150.10	0.60	-14.72	2.86	169.70	-5.13	-15.62	2.76	176.20	-0.11	-22.30	-15.21				
N Tryon St & E Sugarcreek Rd	N Tryon & Matheson Ave/W 30th	136.6	0.3	0.7	28.6	182.7	1.3	4.3	37.8	146.6	-1.1	16.5	23.5				
N Tryon & Matheson Ave/W 30th	N Tryon St & Dalton Ave	94.90	1.16	-2.42	29.98	110.00	2.73	-8.00	-28.81	84.80	4.95	0.47	-6.21				
6/5/2013	11 AM- 1 PM	Run 1 (Time) 11:00:45				Run 2 (Time) 11:36:42				Run 3 (Time) 12:29:10							
N Tryon St & E WT Harris Blvd	N Tryon St & I-85 Conn/Sandy Ave	240.10	2.04	-30.99	-6.70	342.80	0.06	-56.71	-35.67	486.00	0.21	-61.38	-46.80				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & Old Concord Rd	147.40	-0.27	7.67	68.16	213.00	-0.94	-27.35	9.94	145.40	0.41	12.04	65.68				
N Tryon St & Old Concord Rd	N Tryon St & E Sugarcreek Rd	130.2	1.4	-2.8	22.7	213.6	-1.2	-45.6	-30.4	125.7	0.2	4.7	8.2				
N Tryon St & E Sugarcreek Rd	N Tryon & Matheson Av/W 30th	131.20	-0.91	14.41	49.94	133.50	1.87	28.01	65.75	169.60	0.24	-2.71	15.82				
N Tryon & Matheson Av/W 30th	N Tryon St & Dalton Ave	113.00	-2.65	-22.57	-1.49	99.30	1.71	1.91	21.96	96.40	2.70	-1.14	-23.29				
6/5/2013	4 PM- 6 PM	Run 1 (Time) 04:00:46				Run 2 (Time) 04:51:45				Run 3 (Time) 05:41:50							
N Tryon St & E WT Harris Blvd	N Tryon St & I-85 Conn/Sandy Ave	341.90	0.32	-50.60	-23.95	238.20	-0.08	-27.88	23.93	394.10	-0.03	-55.95	-44.30				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & Old Concord Rd	216.1	-1.9	-18.1	26.7	241.0	1.2	-30.5	28.2	209.5	0.7	-22.2	52.4				
N Tryon St & Old Concord Rd	N Tryon St & E Sugarcreek Rd	168.30	2.20	-14.08	-8.68	166.50	0.30	-23.72	5.35	165.70	0.78	-18.53	18.44				
N Tryon St & E Sugarcreek Rd	N Tryon & Matheson Av/W 30th	228.60	-0.26	-25.24	5.08	239.00	0.00	-39.04	22.38	225.60	-0.27	-24.25	10.54				
N Tryon & Matheson Av/W 30th	N Tryon St & Dalton Ave	96.90	1.14	-1.65	65.57	88.30	-0.34	11.21	-9.40	112.30	0.62	-15.14	26.48				
6/6/2013	7 AM- 10 AM	Run 1 (Time) 6:58:30				Run 2 (Time) 7:36:22				Run 3 (Time) 8:36:13				Run 4 (Time) 9:24:05			
N Tryon St & E WT Harris Blvd	N Tryon St & I-85 Conn/Sandy Ave	252.7	0.1	-42.5	-9.3	367.7	-1.0	-56.1	-24.0	389.0	-0.8	-59.8	-19.5	280.1	-1.1	-41.2	20.1
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & Old Concord Rd	165.80	0.72	-6.63	24.22	189.50	1.85	-18.31	10.23	170.30	1.59	-6.81	50.59	160.20	0.50	1.69	68.20
N Tryon St & Old Concord Rd	N Tryon St & E Sugarcreek Rd	190.60	0.73	-32.82	-16.78	170.20	-0.12	-20.39	7.58	175.60	1.94	-24.43	-26.10	123.00	0.81	1.63	45.88
N Tryon St & E Sugarcreek Rd	N Tryon & Matheson Av/W 30th	148.30	-2.23	-7.22	10.47	169.10	-0.06	4.61	2.18	165.30	-2.60	-3.33	0.02	163.90	2.50	-5.49	34.42
N Tryon & Matheson Av/W 30th	N Tryon St & Dalton Ave	99.10	0.91	-6.56	-32.37	79.80	1.50	26.82	17.99	77.90	3.98	12.32	43.92	107.50	0.47	-5.86	20.94
6/6/2013	3 PM- 6 PM	Run 1 (Time) 02:59:50				Run 2 (Time) 03:51:30				Run 3 (Time) 05:04:35							
N Tryon St & E WT Harris Blvd	N Tryon St & I-85 Conn/Sandy Ave	452.4	-0.1	-60.5	-65.1	385.4	0.2	-46.2	-54.4	405.6	-0.1	-58.3	-18.5				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & Old Concord Rd	186.80	1.18	-2.52	71.22	246.50	1.01	-33.91	38.39	190.20	-0.63	-14.35	90.98				
N Tryon St & Old Concord Rd	N Tryon St & E Sugarcreek Rd	200.80	0.10	-26.59	0.13	158.70	0.19	-20.54	63.86	132.60	-3.47	-0.60	35.35				
N Tryon St & E Sugarcreek Rd	N Tryon & Matheson Av/W 30th	176.10	-0.62	-6.19	52.56	213.60	0.19	-35.58	8.28	210.10	2.33	-18.66	32.35				
N Tryon & Matheson Av/W 30th	N Tryon St & Dalton Ave	146.60	0.95	-38.61	2.61	111.60	-3.23	-14.52	-2.59	97.40	-8.62	0.82	19.83				

Table A-4: Percentage Difference in Travel Times on N Tryon St, Outbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/5/2013	7 AM- 9 AM	Run 1 (Time) 7:19:5				Run 2 (Time) 8:04:20				Run 3 (Time) 8:42:21							
N Tryon St & Dalton Ave	N Tryon & Matheson Ave/W 30th	86.20	4.41	1.51	97.17	89.70	1.45	6.24	51.59	83.10	3.49	14.68	113.25				
N Tryon & Matheson Ave/W 30th	N Tryon St & E Sugarcreek Rd	175.70	0.74	-12.12	53.47	136.30	0.51	13.35	58.72	231.00	-1.30	-14.42	19.74				
N Tryon St & E Sugarcreek Rd	N Tryon St & Old Concord Rd	189.00	0.53	-25.40	6.50	172.50	0.29	-19.94	83.08	154.20	3.11	-11.74	105.27				
N Tryon St & Old Concord Rd	N Tryon St & I-85 Conn/Sandy Ave	144.5	-0.3	49.2	78.9	167.1	-0.1	1.9	59.7	208.5	-0.2	-8.7	57.8				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & E WT Harris Blvd	285.90	1.08	-38.54	-21.77	246.50	0.61	-35.70	-18.01	246.10	0.37	-34.34	-16.55				
6/5/2013	11 AM- 1 PM	Run 1 (Time) 11:17:10				Run 2 (Time) 12:04:45				Run 3 (Time) 1:04:20							
N Tryon St & Dalton Ave	N Tryon & Matheson Ave/W 30th	120.50	2.90	-27.39	37.37	102.50	1.46	-14.63	64.68	157.50	1.59	-37.65	-9.99				
N Tryon & Matheson Ave/W 30th	N Tryon St & E Sugarcreek Rd	135.80	-0.59	91.61	76.46	203.90	0.54	-30.75	51.44	145.70	-1.17	9.40	43.39				
N Tryon St & E Sugarcreek Rd	N Tryon St & Old Concord Rd	179.1	1.1	-28.0	-12.5	136.9	0.8	9.3	101.8	189.2	0.4	-22.3	-10.0				
N Tryon St & Old Concord Rd	N Tryon St & I-85 Conn/Sandy Ave	156.40	-0.26	11.76	69.23	143.60	-0.42	36.49	86.57	142.80	-1.26	25.77	116.74				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & E WT Harris Blvd	294.60	0.81	-40.87	-36.64	424.10	0.21	-48.95	-50.01	453.20	0.84	-60.55	-46.69				
6/5/2013	4 PM- 6 PM	Run 1 (Time) 4:20:3				Run 2 (Time) 5:13:30				Run 3 (Time) 6:07:20							
N Tryon St & Dalton Ave	N Tryon & Matheson Ave/W 30th	117.20	0.68	-10.84	22.35	104.30	0.67	-5.85	37.26	81.80	-0.98	20.05	123.50				
N Tryon & Matheson Ave/W 30th	N Tryon St & E Sugarcreek Rd	223.5	0.2	-14.9	16.0	326.7	-0.2	-46.0	-25.7	227.0	0.4	-27.4	-14.3				
N Tryon St & E Sugarcreek Rd	N Tryon St & Old Concord Rd	211.00	0.47	-32.75	-15.80	194.40	0.31	-17.75	22.19	125.60	1.11	27.31	54.36				
N Tryon St & Old Concord Rd	N Tryon St & I-85 Conn/Sandy Ave	199.70	0.15	-12.47	28.04	220.40	-1.09	-18.51	17.67	194.50	0.26	-4.99	56.78				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & E WT Harris Blvd	383.90	0.03	-56.45	-18.12	265.10	-0.04	-34.25	3.19	275.30	0.62	-30.29	-38.95				
6/6/2013	7 AM- 10 AM	Run 1 (Time) 07:17:30				Run 2 (Time) 08:04:10				Run 3 (Time) 08:57:33				Run 4 (Time) 09:13			
N Tryon St & Dalton Ave	N Tryon & Matheson Ave/W 30th	88.9	1.2	0.9	73.6	83.6	0.5	14.0	104.8	83.8	1.4	17.2	133.4	79.9	0.1	22.9	146.3
N Tryon & Matheson Ave/W 30th	N Tryon St & E Sugarcreek Rd	163.90	0.06	-5.74	60.11	141.10	-0.07	9.50	83.44	265.80	0.45	-35.85	-19.07	209.90	0.52	-18.77	4.01
N Tryon St & E Sugarcreek Rd	N Tryon St & Old Concord Rd	180.50	-0.28	-3.21	-34.81	140.20	2.00	-1.43	-10.21	130.50	1.15	-6.74	-4.43	183.10	0.49	-33.59	-27.19
N Tryon St & Old Concord Rd	N Tryon St & I-85 Conn/Sandy Ave	217.40	0.74	-0.92	-0.95	205.30	-0.15	-17.10	31.66	184.80	-0.97	-10.28	46.27	188.80	0.11	-12.18	49.61
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & E WT Harris Blvd	209.50	1.67	-16.13	-21.45	238.50	0.63	-33.54	-34.92	195.70	0.66	-18.09	-16.88	335.60	0.42	-52.23	-37.49
6/6/2013	3 PM- 6 PM	Run 1 (Time) 03:22:30				Run 2 (Time) 04:19:25				Run 3 (Time) 05:35:15							
N Tryon St & Dalton Ave	N Tryon & Matheson Ave/W 30th	162.8	1.4	-37.8	-8.5	129.9	-3.8	-24.4	34.0	201.0	1.0	-51.1	-25.1				
N Tryon & Matheson Ave/W 30th	N Tryon St & E Sugarcreek Rd	208.50	-0.24	-20.96	1.60	322.80	-0.25	-33.46	-13.89	236.20	-0.51	-27.86	0.64				
N Tryon St & E Sugarcreek Rd	N Tryon St & Old Concord Rd	227.70	0.57	-38.56	-1.25	187.00	0.00	-24.17	22.07	190.40	-0.21	-16.12	31.74				
N Tryon St & Old Concord Rd	N Tryon St & I-85 Conn/Sandy Ave	186.60	0.75	-8.79	44.86	316.60	0.13	-44.79	-3.26	1160.00	0.09	-84.52	-73.60				
N Tryon St & I-85 Conn/Sandy Ave	N Tryon St & E WT Harris Blvd	387.90	0.54	-49.86	-32.40	1476.70	-0.39	-90.22	-84.27	1314.20	-0.09	-84.03	-82.33				

Table A-5: Percentage Difference in Travel Times on Providence Rd, Inbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/11/2013	7 AM - 9 AM	Run 1 (Time) 07:14:25				Run 2 (Time) 07:58:10				Run 3 (Time) 08:38:30							
Prov Rd& Pineville-Matthews Rd	ProvRd & Alexander Rd/Rea Rd	105.10	2.76	-3.52	21.50	102.30	0.68	15.54	33.82	104.40	0.57	4.60	28.83				
ProvRd & Alexander Rd/Rea Rd	ProvRd & Sardis Rd/Fairview Rd	341.10	-0.32	-22.96	-10.84	320.80	-0.56	-22.19	-9.82	328.80	0.06	-29.38	-11.56				
ProvRd & Sardis Rd/Fairview Rd	Prov Rd & Sharon Amity Rd/Sharon	131.20	1.37	-3.96	53.20	137.70	-1.96	30.72	4.94	135.10	0.67	-11.18	19.69				
Prov Rd & Sharon Amity Rd/Sharon	Providence Rd & Queens Rd	273.5	0.2	-24.8	33.6	354.3	-0.1	19.1	18.5	302.8	0.1	-15.4	15.4				
6/11/2013	11 AM - 1 PM	Run 1 (Time) 11:19:50				Run 2 (Time) 11:56:43				Run 3 (Time) 12:43:30							
Prov Rd& Pineville-Matthews Rd	ProvRd & Alexander Rd/Rea Rd	115.80	0.17	-26.42	14.08	117.50	0.43	-17.28	15.83	95.50	-0.52	3.66	52.36				
ProvRd & Alexander Rd/Rea Rd	ProvRd & Sardis Rd/Fairview Rd	253.80	0.08	-6.38	30.34	245.20	-0.08	-2.85	16.88	274.70	-0.25	-6.73	11.07				
ProvRd & Sardis Rd/Fairview Rd	Prov Rd & Sharon Amity Rd/Sharon	158.40	0.38	-16.29	-0.25	177.50	0.28	-23.27	-9.07	157.00	0.00	-7.52	-3.44				
Prov Rd & Sharon Amity Rd/Sharon	Providence Rd & Queens Rd	337.1	0.3	-35.4	-5.3	387.6	0.4	-30.7	13.4	279.7	-0.3	16.3	62.8				
6/11/2013	4 PM - 6 PM	Run 1 (Time) 04:18:52				Run 2 (Time) 05:22:00											
Prov Rd& Pineville-Matthews Rd	ProvRd & Alexander Rd/Rea Rd	120.40	0.50	-21.26	8.39	90.40	1.77	9.51	32.63								
ProvRd & Alexander Rd/Rea Rd	ProvRd & Sardis Rd/Fairview Rd	268.70	0.11	-2.42	-5.28	231.10	0.82	8.26	20.81								
ProvRd & Sardis Rd/Fairview Rd	Prov Rd & Sharon Amity Rd/Sharon	188.70	-1.96	-25.60	-27.87	192.40	0.83	-22.66	-16.79								
Prov Rd & Sharon Amity Rd/Sharon	Providence Rd & Queens Rd	470.1	-0.7	-51.5	-40.3	518.4	0.1	-55.1	-47.0								
6/12/2013	7 AM - 10 AM	Run 1 (Time) 07:15:10				Run 2 (Time) 07:48:08				Run 3 (Time) 08:35:04				Run 4 (Time) 09:34:20			
Prov Rd& Pineville-Matthews Rd	ProvRd & Alexander Rd/Rea Rd	102.80	1.17	0.88	-4.47	177.70	0.73	-50.08	-16.99	150.90	0.07	-41.29	-37.11	107.90	0.09	-12.42	-1.58
ProvRd & Alexander Rd/Rea Rd	ProvRd & Sardis Rd/Fairview Rd	341.00	0.59	-25.04	-17.92	239.80	0.08	1.25	55.92	244.60	0.16	-3.03	50.53	239.60	0.17	1.38	36.10
ProvRd & Sardis Rd/Fairview Rd	Prov Rd & Sharon Amity Rd/Sharon	149.40	-0.27	-16.00	3.41	306.00	0.65	-31.57	-14.74	139.60	0.29	23.78	20.85	131.30	1.29	6.09	38.92
Prov Rd & Sharon Amity Rd/Sharon	Providence Rd & Queens Rd	212.8	0.1	-4.9	16.3	263.3	-0.9	2.1	17.1	213.9	0.5	7.6	54.7	284.8	1.1	-16.3	7.2
6/12/2013	3 PM - 6 PM	Run 1 (Time) 03:32:00				Run 2 (Time) 04:09:40				Run 3 (Time) 05:04:20				Run 4 (Time) 05:50:10			
Prov Rd& Pineville-Matthews Rd	ProvRd & Alexander Rd/Rea Rd	117.10	0.77	-15.54	23.31	97.60	1.43	1.33	49.49	121.00	-3.31	-2.40	12.15	92.30	0.76	-1.95	75.41
ProvRd & Alexander Rd/Rea Rd	ProvRd & Sardis Rd/Fairview Rd	321.50	0.16	-24.29	-12.38	235.10	0.38	3.32	25.82	302.10	-1.36	-19.60	-5.20	213.40	0.28	11.34	54.03
ProvRd & Sardis Rd/Fairview Rd	Prov Rd & Sharon Amity Rd/Sharon	209.40	0.29	-29.37	-27.94	178.20	0.45	-23.23	-3.37	201.30	2.33	-28.81	-24.29	183.50	0.82	-17.00	-8.66
Prov Rd & Sharon Amity Rd/Sharon	Providence Rd & Queens Rd	292.6	0.1	-22.2	2.9	322.9	-0.9	-22.2	-10.9	301.3	-0.1	-37.5	4.6	222.1	0.4	5.9	20.2

Table A-6: Percentage Difference in Travel Times on Providence Rd, Outbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/11/2013	7 AM - 9 AM	Run 1 (Time) 06:59:14				Run 2 (Time) 07:43:40				Run 3 (Time) 8:24:00							
Providence Rd & Queens Rd	Prov Rd & Sharon Amity Rd/Sharon	186.70	0.16	8.30	35.89	212.00	0.94	8.68	19.06	221.90	1.40	-3.47	33.53				
Prov Rd & Sharon Amity Rd/Sharon	ProvRd & Sardis Rd/Fairview Rd	200.60	0.20	-33.30	-16.55	177.90	0.06	-24.45	-2.92	194.10	-0.05	-29.83	-12.16				
ProvRd & Sardis Rd/Fairview Rd	ProvRd & Alexander Rd/Rea Rd	235.50	0.21	-4.46	99.15	242.40	-0.99	-4.95	93.48	223.40	-0.18	-1.43	109.94				
ProvRd & Alexander Rd/Rea Rd	Prov Rd& Pineville-Matthews Rd	102.7	1.3	-3.6	56.7	108.8	-2.6	-9.0	47.9	132.0	0.0	-30.5	21.9				
6/11/2013	11 AM - 1 PM	Run 1 (Time) 10:59:34				Run 2 (Time) 11:40:30				Run 3 (Time) 12:25:50							
Providence Rd & Queens Rd	Prov Rd & Sharon Amity Rd/Sharon	320.70	-0.53	-28.34	-26.13	306.90	-0.29	-33.14	-24.44	251.40	1.03	-9.31	5.17				
Prov Rd & Sharon Amity Rd/Sharon	ProvRd & Sardis Rd/Fairview Rd	136.90	0.07	9.57	26.73	122.40	0.49	8.82	43.22	196.10	0.46	-36.97	23.10				
ProvRd & Sardis Rd/Fairview Rd	ProvRd & Alexander Rd/Rea Rd	312.20	0.26	-18.71	50.22	271.60	0.52	-17.16	72.68	286.20	-0.07	-19.50	63.87				
ProvRd & Alexander Rd/Rea Rd	Prov Rd& Pineville-Matthews Rd	153.2	1.8	-13.1	5.0	95.9	2.2	15.1	67.8	134.5	0.4	-18.8	19.6				
6/11/2013	4 PM - 6 PM	Run 1 (Time) 04:00:45				Run 2 (Time) 04:43:15											
Providence Rd & Queens Rd	Prov Rd & Sharon Amity Rd/Sharon	348.10	0.26	-38.98	-35.25	380.60	0.11	-37.89	-46.95								
Prov Rd & Sharon Amity Rd/Sharon	ProvRd & Sardis Rd/Fairview Rd	121.80	1.81	-0.99	48.60	409.60	-0.15	1.95	-56.93								
ProvRd & Sardis Rd/Fairview Rd	ProvRd & Alexander Rd/Rea Rd	337.10	-0.03	-36.10	39.13	333.30	-0.09	-36.81	40.71								
ProvRd & Alexander Rd/Rea Rd	Prov Rd& Pineville-Matthews Rd	138.8	-1.3	-21.3	15.9	173.6	0.2	5.8	-7.3								
6/12/2013	7 AM - 10 AM	Run 1 (Time) 07:00:14				Run 2 (Time) 07:34:30				Run 3 (Time) 08:06:32				Run 4 (Time) 08:50:18			
Providence Rd & Queens Rd	Prov Rd & Sharon Amity Rd/Sharon	251.50	0.20	-19.72	-9.50	186.00	0.54	5.75	9.73	231.20	0.35	-17.21	0.87	258.00	0.39	-21.43	3.80
Prov Rd & Sharon Amity Rd/Sharon	ProvRd & Sardis Rd/Fairview Rd	139.90	-0.64	-5.22	36.24	125.90	0.08	11.12	36.93	122.60	1.96	5.30	32.87	154.10	3.18	-11.75	8.31
ProvRd & Sardis Rd/Fairview Rd	ProvRd & Alexander Rd/Rea Rd	318.60	0.13	-30.98	-53.83	304.80	0.39	-24.48	-39.57	303.50	0.49	-24.15	-12.59	303.50	0.49	-22.37	-41.22
ProvRd & Alexander Rd/Rea Rd	Prov Rd& Pineville-Matthews Rd	97.4	-0.4	1.0	60.9	104.2	0.8	-2.8	50.4	103.9	1.1	-0.5	50.8	121.9	-1.6	-11.6	28.5
6/12/2013	3 PM - 6 PM	Run 1 (Time) 03:16:50				Run 2 (Time) 03:50:30				Run 3 (Time) 04:35:20				Run 4 (Time) 05:23:30			
Providence Rd & Queens Rd	Prov Rd & Sharon Amity Rd/Sharon	251.60	-0.24	-4.17	-2.58	380.60	-0.16	-41.93	-38.54	270.00	0.37	-17.85	-14.15	520.30	0.13	-51.82	-36.94
Prov Rd & Sharon Amity Rd/Sharon	ProvRd & Sardis Rd/Fairview Rd	134.00	2.24	17.76	61.34	123.60	-0.49	-0.57	56.39	390.30	0.18	-57.31	-11.79	261.70	0.50	-31.26	46.08
ProvRd & Sardis Rd/Fairview Rd	ProvRd & Alexander Rd/Rea Rd	227.80	0.09	-5.36	103.99	298.80	0.40	-15.09	55.52	324.70	0.09	-25.65	43.09	318.90	0.03	-24.37	45.69
ProvRd & Alexander Rd/Rea Rd	Prov Rd& Pineville-Matthews Rd	101.8	-4.7	36.4	53.9	130.1	1.5	24.8	20.4	241.2	0.3	-49.3	-35.0	295.1	0.3	-52.7	-46.9

Table A-7: Percentage Difference in Travel Times on Sharon Rd, Inbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/18/2013	7 AM - 9 AM	Run 1 (Time) 7:47:26				Run 2 (Time) 8:37:52				Run 3 (Time) 9:17:42							
Park Rd & Birnen Dr/Johnson Rd	Park Rd & Sharon Rd W/Gleneagles	165.50	0.30	-9.43	-25.50	158.80	0.13	-0.19	-9.13	157.50	-0.95	-11.87	-2.73				
Park Rd & Sharon Rd W/Gleneagles	Sharon Rd & Quail Hollow Rd	190.40	0.32	-33.72	-54.57	194.60	0.72	-16.44	-55.14	195.90	0.05	-17.71	-50.13				
Sharon Rd & Quail Hollow Rd	Sharon Rd & Fairview Rd	303.10	-0.03	-48.70	-36.98	160.90	0.06	0.19	17.28	150.20	1.20	-12.05	-4.66				
Sharon Rd & Fairview Rd	Sharon Rd & Wendover Rd	312.6	-6.0	-41.7	-59.6	186.7	-3.1	-2.0	-7.6	238.3	0.3	-16.7	-47.0				
Sharon Rd & Wendover Rd	Queens Rd & Providence Rd	319.30	0.53	-22.08	-15.19	297.60	0.13	33.17	1.21	345.80	0.06	6.68	-13.10				
6/18/2013	11 AM - 1 PM	Run 1 (Time) 11:24:00				Run 2 (Time) 12:08:49				Run 3 (Time) 12:59:45							
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	135.00	0.00	8.22	-11.04	130.90	0.08	14.67	33.61	202.80	0.10	-26.08	-6.76				
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	187.60	0.21	-10.34	-59.49	175.50	-0.28	-9.80	-56.87	196.80	0.61	-22.10	-54.83				
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	147.6	0.3	-1.4	11.7	249.9	0.4	-43.7	-34.4	179.1	-0.1	-13.1	23.6				
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	206.90	0.05	-5.85	-35.38	256.20	0.31	15.77	-40.20	246.00	3.25	-16.10	-41.18				
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	294.30	1.60	24.53	-20.97	375.00	0.27	-2.35	-32.37	359.80	0.61	1.86	-21.76				
6/18/2013	4 PM - 6 PM	Run 1 (Time) 04:38:30				Run 2 (Time) 05:33:59											
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	184.80				184.70											
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	204.1				346.9											
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	221.40				229.20											
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	323.50				258.70											
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	277.60				239.80											
6/19/2013	7 AM - 10 AM	Run 1 (Time) 07:15:29				Run 2 (Time) 08:13:19				Run 3 (Time) 09:00:48				Run 4 (Time) 09:53:27			
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	175.9	1.8	-12.3	-33.0	160.4	1.0	-6.6	20.6	145.7	0.9	3.0	-4.5	136.8	0.1	6.7	-13.2
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	188.80	1.17	-18.86	-58.26	198.90	2.06	-19.91	-52.79	185.60	0.22	-17.30	-49.62	187.00	1.07	-16.74	-58.56
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	151.30	-1.52	-17.65	-18.90	296.00	-1.69	-45.51	-40.47	243.50	-0.62	-40.37	-33.35	232.60	-1.98	-46.35	-23.13
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	178.60	1.34	8.57	-28.16	223.00	2.24	-6.41	-47.35	247.90	1.25	-18.43	-42.88	224.00	0.89	-16.29	-43.39
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	222.50	0.22	61.62	3.33	295.50	2.20	38.04	3.72	264.90	-0.34	51.49	-0.98	305.80	0.07	19.06	-24.56
6/19/2013	3 PM - 6 PM	Run 1 (Time) 15:21:33				Run 2 (Time) 16:01:20				Run 3 (Time) 17:10:00				Run 4 (Time) 17:57:20			
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	128.6	1.1	16.7	10.7	138.4	0.4	5.4	13.9	138.3	0.5	5.6	-12.6	190.1	0.5	-25.1	-36.0
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	158.50	0.95	-4.42	-47.44	184.90	0.59	-18.93	-56.41	215.20	0.37	-28.53	-53.90	247.30	0.69	-36.47	-59.44
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	194.50	-0.26	-29.92	0.98	222.30	-1.03	-36.75	-32.25	200.90	-0.45	-32.11	-5.33	210.00	0.00	-35.05	7.95
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	288.10	0.31	-35.75	-47.73	291.60	0.82	-29.32	-53.29	304.40	1.84	-26.87	-42.94	287.60	-0.21	-23.82	-46.04
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	410.80	-0.19	-4.89	-18.48	285.60	0.14	37.54	-5.74	343.00	0.58	20.09	-12.22	344.60	0.12	11.09	-16.72

Table A-8: Percentage Difference in Travel Times on Sharon Rd, Outbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/18/2013	7 AM - 9 AM	Run 1 (Time) 7:19:45				Run 2 (Time) 8:12:40				Run 3 (Time) 8:57:40							
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	222.60	3.32	-15.32	1.44	258.10	1.90	-20.96	-5.89	270.50	-2.77	-25.77	-1.37				
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	208.60	3.55	-5.23	6.23	413.10	1.43	-45.34	-37.33	291.60	1.85	-24.93	-3.05				
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	190.50	0.26	-36.90	-52.18	132.60	0.30	-1.21	-15.38	124.40	4.50	5.39	-33.84				
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	212.2	0.4	-29.7	7.3	276.2	-0.1	-42.5	-14.8	271.8	1.2	-43.7	-20.0				
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	173.40	0.35	-13.90	15.80	163.30	0.43	-10.96	22.54	162.40	-1.48	-10.47	11.70				
6/18/2013	11 AM - 1 PM	Run 1 (Time) 11:04:05				Run 2 (Time) 11:19:16				Run 3 (Time) 12:38:26							
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	230.00	-1.74	-15.35	11.96	208.50	0.24	-5.90	19.71	257.20	-0.08	-21.77	8.40				
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	292.80	2.12	-25.44	-31.05	368.60	0.38	-39.69	-44.25	331.70	1.60	-27.40	-16.94				
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	164.6	0.9	-17.9	-45.3	144.9	-0.6	-6.7	-37.6	135.4	-4.0	-0.1	-34.8				
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	238.20	-0.08	-39.25	-9.66	146.20	-0.82	3.21	49.04	220.80	-0.36	-25.86	-5.57				
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	127.10	-0.08	11.49	48.94	167.80	0.72	-15.55	19.43	174.40	0.92	-14.33	29.19				
6/18/2013	4 PM - 6 PM	Run 1 (Time) 16:17:00				Run 2 (Time) 17:02:29											
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	267.60				231.10											
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	382.9				451.6											
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	142.30				169.30											
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	201.30				164.70											
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	147.00				153.00											
6/19/2013	7 AM - 10 AM	Run 1 (Time) 06:58:31				Run 2 (Time) 07:44:04				Run 3 (Time) 08:35:54				Run 4 (Time) 09:32:30			
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	208.3	0.3	-8.8	8.2	243.8	0.5	-19.6	12.6	271.8	3.0	-29.5	7.6	267.7	0.5	-27.8	1.1
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	217.00	0.00	-10.18	-17.19	217.60	-0.28	1.15	10.48	343.10	2.30	-36.29	-34.19	273.50	0.18	-22.67	-11.19
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	125.20	0.64	-3.99	-11.42	152.00	0.00	-13.82	-42.83	135.40	0.44	3.03	-29.91	182.60	0.22	-34.17	-61.94
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	156.00	-0.64	-5.26	41.60	257.40	0.23	-41.80	-13.60	272.50	0.55	-37.21	-24.15	234.70	0.55	-35.28	6.14
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	159.70	0.81	-3.88	25.42	163.40	0.98	-21.36	22.58	162.30	0.43	-10.41	30.87	132.30	0.53	7.86	35.60
6/19/2013	3 PM - 6 PM	Run 1 (Time) 15:03:00				Run 2 (Time) 15:43:15				Run 3 (Time) 16:27:30				Run 4 (Time) 17:33:00			
Queens Rd & Providence Rd	Sharon Rd & Wendover Rd	218.6	0.2	-4.9	34.9	213.5	0.7	-1.0	40.0	251.3	1.1	-19.8	18.3	247.3	2.3	-12.0	8.1
Sharon Rd & Wendover Rd	Sharon Rd & Fairview Rd	275.50	0.18	-13.58	7.70	247.90	0.04	-5.89	2.50	285.80	2.87	4.90	-14.17	434.90	2.55	-43.69	-13.61
Sharon Rd & Fairview Rd	Sharon Rd & Quail Hollow Rd	125.00	0.80	-6.40	-46.16	116.60	0.34	15.95	-33.62	132.40	0.45	8.91	-30.59	182.30	-0.16	-23.42	-39.71
Sharon Rd & Quail Hollow Rd	Park Rd & Sharon Rd W/Gleneagles	197.00	0.51	-17.92	3.35	252.70	0.51	-39.61	-11.32	186.30	0.38	-17.28	28.07	159.60	-0.38	8.15	77.13
Park Rd & Sharon Rd W/Gleneagles	Park Rd & Birnen Dr/Johnson Rd	161.90	0.68	-18.72	29.96	141.20	0.57	-11.05	-3.97	138.60	1.73	-0.29	26.41	218.90	0.96	0.91	-5.76

Table A-8: Percentage Difference in Travel Times on South Blvd, Inbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/29/2013	7 AM - 9 AM	Run 1 (Time) 07:14:00				Run 2 (Time) 07:47:00				Run 3 (Time) 08:23:00				Run 4 (Time) 08:52:00											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	145.60	0.27	-41.90	21.36	141.10	0.64	-36.47	26.79	92.90	0.11	-0.34	60.06	79.60	4.27	3.12	129.65								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	151.70	0.20	-13.78	64.21	301.10	0.63	-54.93	-29.49	187.30	0.37	-26.00	9.61	124.90	0.08	1.84	70.06								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	258.60	0.93	-10.21	-15.74	209.50	-0.24	0.53	12.84	311.00	0.32	-32.28	-11.86	294.10	-0.03	-11.87	-11.97								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	115.8	1.0	-22.3	13.5	181.2	-2.3	-47.0	-21.7	84.1	1.1	13.4	85.1	87.7	1.5	6.0	63.9								
5/29/2013	11 AM - 1 PM	Run 1 (Time) 11:15:00				Run 2 (Time) 11:49:00				Run 3 (Time) 12:17:00				Run 4 (Time) 12:55:00											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	82.50	0.61	8.65	48.97	91.10	0.99	11.77	-18.33	90.00	1.11	31.33	-27.33	92.90	2.26	-0.34	22.28								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	128.30	0.55	1.95	72.10	115.80	0.17	15.03	120.29	137.50	0.36	-7.05	77.67	143.90	0.07	-4.52	46.21								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	323.40	0.19	-40.45	-29.47	323.80	0.06	-34.96	-22.33	246.70	0.53	-14.63	14.19	268.70	0.11	-13.58	2.94								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	126.6	0.3	-24.2	7.7	123.9	0.9	-17.2	40.0	119.8	-2.3	-22.4	50.0	116.0	1.7	-24.5	39.4								
5/29/2013	4 PM - 6 PM	Run 1 (Time) 4:46:50				Run 2 (Time) 5:28:00				Run 3 (Time) 6:20:10				Run 4 (Time) 6:49:30											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	150.50	16.28	-36.54	-5.32	184.00	-3.80	-49.68	1.79	173.00	1.16	-46.47	21.68	77.50	-0.65	23.23	124.65								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	146.30	36.71	4.99	66.58	225.80	-0.35	-22.94	4.74	211.10	0.43	-32.35	57.13	214.00	0.00	-32.71	15.75								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	244.20	-40.21	-11.06	-6.06	319.80	0.06	-45.97	-22.17	380.20	-0.05	-31.83	-28.85	384.90	0.03	-47.00	-24.03								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	157.9	-43.6	-16.8	-1.3	163.1	0.6	-37.1	-0.7	146.5	0.3	-50.9	-5.0	115.2	1.6	-30.7	26.0								
5/30/2013	7 AM - 10 AM	Run 1 (Time) 07:18:00				Run 2 (Time) 07:53:00				Run 3 (Time) 08:29:00				Run 4 (Time) 08:58:00				Run 5 (Time) 09:33:00				Run 6 (Time) 09:58:00			
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	139.20	0.57	-37.86	-37.57	77.40	2.07	15.81	-7.24	141.60	0.28	-32.56	-3.04	122.40	-0.33	-19.56	-14.62	179.90	0.06	-50.19	-51.86	88.80	0.23	44.46	37.05
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	125.60	1.11	20.38	59.47	113.50	1.32	22.64	78.94	177.90	0.06	-24.45	33.05	162.20	1.73	-13.07	23.12	113.90	0.97	16.94	124.58	121.30	1.40	17.72	83.76
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	245.50	-0.61	-16.90	-17.76	327.50	0.15	-35.69	-23.54	255.90	-0.35	-15.12	-11.14	311.80	-0.90	-38.23	-29.22	276.30	-0.11	-26.17	-2.42	281.60	1.56	-25.43	-25.92
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	85.2	3.3	-0.7	74.3	188.5	0.3	-49.1	-34.5	89.3	-0.3	7.5	38.6	95.6	1.5	-2.7	65.8	121.5	-0.4	-21.0	32.0	116.0	0.9	-17.0	38.3
5/30/2013	3 PM - 6 PM	Run 1 (Time) 03:14:00				Run 2 (Time) 3:46:00				Run 3 (Time) 04:24:00				Run 4 (Time) 04:56:00				Run 5(Time) 05:50:00							
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	176.70	-0.96	-4.30	-23.15	164.50	0.91	-32.89	-15.02	181.70	-2.04	-47.44	-23.06	197.30	0.35	-42.02	-11.35	148.60	0.27	-37.82	-35.87				
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	146.40	-0.96	-5.94	118.92	222.20	-0.09	-30.06	35.55	125.40	-1.12	32.70	140.19	236.40	1.52	-39.30	33.16	226.40	0.27	-43.82	33.57				
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	309.00	-0.32	-9.09	-11.26	395.70	0.33	-45.03	-37.53	410.60	-0.63	-13.57	-39.80	358.60	0.39	-32.82	-28.75	242.70	0.12	-10.38	11.62				
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	157.1	-0.7	-38.4	13.6	153.9	0.1	-30.3	-1.0	157.9	-1.2	-32.1	-3.5	160.2	0.5	-37.7	-8.1	148.5	0.3	-32.5	11.6				

Table A-8: Percentage Difference in Travel Times on South Blvd, Outbound Direction

From Intersection	To Intersection	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
5/29/2013	7 AM - 9 AM	Run 1 (Time) 07:00				Run 2 (Time) 07:32				Run 3 (Time) 08:08				Run 4 (Time) 08:39											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	172.40	1.51	-46.64	-34.40	171.20	0.47	-42.76	-32.36	168.50	0.30	-51.10	-33.71	66.30	1.06	129.26	66.21								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	200.10	-0.05	-12.74	49.13	220.30	0.32	-7.94	32.96	256.90	0.43	-18.72	16.35	261.10	0.73	-18.65	18.12								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	145.40	0.41	-18.71	-15.13	156.20	2.43	-18.18	-21.00	130.60	0.31	35.94	-6.81	112.00	2.68	30.71	3.39								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	85.9	3.6	-6.6	71.6	93.7	0.3	6.2	57.3	150.5	1.0	-12.9	4.1	150.6	0.3	-28.3	12.1								
5/29/2013	11 AM - 1 PM	Run 1 (Time) 10:58:00				Run 2 (Time) 11:32:00				Run 3 (Time) 12:30:00				Run 4 (Time) 12:34:00											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	133.30	0.53	-21.53	3.08	140.40	-1.00	-25.50	-2.35	134.70	0.22	-35.26	-3.04	140.90	1.49	-23.21	20.09								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	191.70	1.20	7.67	61.45	225.10	0.84	-17.90	38.92	263.20	0.68	-13.60	5.05	284.40	-0.84	-25.11	0.81								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	119.20	-1.01	-6.88	13.67	121.90	0.90	-0.57	-0.82	117.60	1.19	21.94	57.74	120.10	-0.08	30.39	13.99								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	102.3	1.7	-19.5	61.2	120.2	-0.2	-25.2	40.8	119.7	-0.6	-24.9	33.8	112.2	0.7	60.6	31.2								
5/29/2013	4 PM - 6 PM	Run 1 (Time) 04:29				Run 2 (Time) 05:00:40				Run 3 (Time) 05:46				Run 4 (Time) 06:38											
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	109.80	0.18	-20.58	27.60	233.40	0.69	-100.00	-31.06	190.40	-0.21	-40.97	-15.02	102.30	2.64	5.77	47.31								
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	216.80	0.09	-15.04	43.87	173.00	0.00	-100.00	89.54	220.40	0.27	-6.35	48.00	220.30	0.32	-3.31	45.76								
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	183.20	0.98	-23.69	-37.55	115.80	1.90	-100.00	16.75	298.90	0.37	-56.44	-48.71	119.00	3.36	31.60	58.32								
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	273.1	-0.8	-72.9	-27.0	321.4	1.1	-100.0	-40.6	878.6	0.0	-72.6	-79.1	74.7	-0.9	141.2	139.0								
5/30/2013	7 AM - 10 AM	Run 1 (Time) 07:06				Run 2 (Time) 07:32				Run 3 (Time) 08:15				Run 4 (Time) 08:44				Run 5 (Time) 09:14				Run 6 (Time) 09:47			
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	179.00	1.12	-49.94	-19.39	164.90	0.06	-40.57	-37.96	170.80	0.12	-42.62	-28.92	179.00	0.00	-32.18	-34.41	170.00	0.00	-51.53	-25.71	142.80	1.54	-31.37	0.07
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	173.30	-0.17	24.99	72.07	280.20	-0.07	-30.19	14.60	293.40	1.23	-29.45	3.20	218.20	0.37	-5.13	42.85	249.10	-0.04	-17.14	8.55	198.10	-0.05	4.49	40.69
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	142.40	-0.28	-22.89	-23.53	152.10	1.91	-19.92	-20.84	135.40	-1.77	-6.50	-16.99	116.80	1.03	69.01	20.55	142.40	1.83	-19.10	18.75	127.60	-0.47	-3.13	3.61
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	123.5	2.0	-4.8	5.8	153.6	-0.4	-43.1	-12.5	98.5	-1.5	-11.3	42.5	134.4	0.4	-35.0	3.8	95.7	-0.7	-16.2	83.6	72.0	2.8	17.8	75.4
5/30/2013	3 PM - 6 PM	Run 1 (Time) 02:59				Run 2 (Time) 03:29				Run 3 (Time) 04:04				Run 4 (Time) 04:41:30				Run 5 (Time) 05:17							
South Blvd and E Woodlawn Rd	South Blvd and Tyvola Rd	110.00	0.91	-10.55	24.00	106.60	0.38	36.49	51.03	100.10	-0.10	3.70	28.57	101.20	1.78	3.85	36.46	347.20	-0.06	-36.49	-26.64				
South Blvd and Tyvola Rd	South Blvd & Arrowood /Starbrook	245.50	0.20	-22.40	15.52	226.50	0.22	-5.56	37.00	225.20	0.80	-5.11	31.22	259.30	0.27	-28.69	27.00	222.40	1.17	-3.69	46.99				
South Blvd & Arrowood /Starbrook	South Blvd & Sharon Rd	119.90	0.92	8.76	11.01	123.80	0.97	-4.60	20.19	177.30	0.39	-27.41	-17.32	117.50	0.43	-5.11	12.68	121.90	0.90	8.37	31.17				
South Blvd & Sharon Rd	South Blvd & AMC Carolina Pavilion 22	83.9	-1.1	1.2	115.9	87.1	1.0	14.4	65.9	99.0	2.0	53.5	36.8	133.6	1.0	-32.4	5.5	200.3	0.3	-39.9	-28.0				

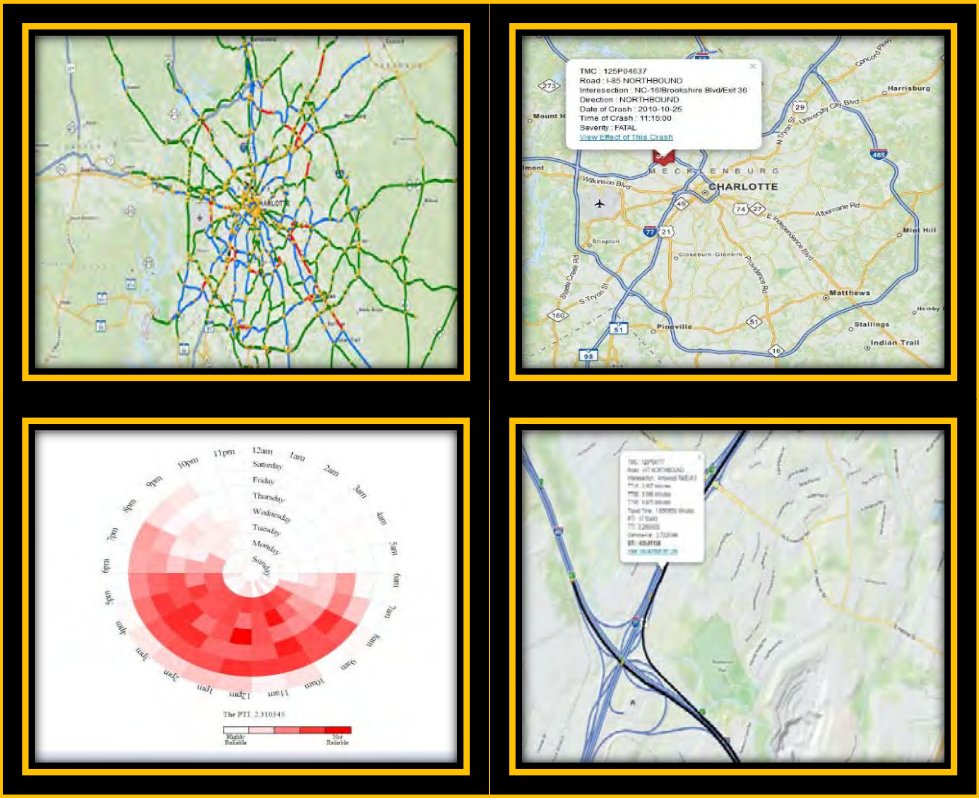
Table A-9: Percentage Difference in Travel Times on I-85, Inbound Direction

Location Name	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/25/2013 from 7 AM - 9 AM	Run 1 (Time) 7:16:08 AM				Run 2 (Time) 7:49:33 AM				Run 3 (Time) 8:19:32 AM				Run 4 (Time) 8:44:15 AM							
Between Exits 41 and 42	92.00	0.00	25.00	-35.72	90.00	0.00	27.78	-33.18	86.00	0.00	32.33	-28.29	102.30	-7.14	11.83	-41.19				
University City Blvd (Exit 43)	95.00	0.00	-9.05	-41.12	91.00	0.00	-6.37	-22.98	91.00	0.00	-7.69	-34.09	88.90	7.99	-4.16	-36.81				
W WT Harris Blvd (Exit 45B)	49.00	0.00	-15.51	-14.51	47.00	0.00	-10.64	-11.15	50.40	-4.76	-20.24	-19.90	51.50	-2.91	-23.11	-15.09				
W Mallard Creek Church Rd (Exit 46)	112.0	0.0	-15.9	-9.9	104.0	0.0	-6.0	-4.5	110.3	-8.4	-19.5	-11.5	87.3	24.9	0.3	27.2				
6/25/2013 from 11 AM - 1 PM	Run 1 (Time) 11:03:27 AM				Run 2 (Time) 11:27:57 AM				Run 3 (Time) 11:51:30 PM				Run 4 (Time) 12:16:12 PM				Run 5 (Time) 12:44:09 PM			
Between Exits 41 and 42	91.20	-0.22	28.07	-32.97	91.50	-1.64	114.40	-32.30	91.70	-0.76	28.03	-35.29	91.80	0.22	1114.60	-32.68	90.70	0.33	26.79	-34.79
University City Blvd (Exit 43)	92.60	-0.65	-7.56	-36.84	92.60	0.43	-57.88	-17.98	91.20	-0.22	-8.55	-35.00	92.60	1.51	-9.29	-35.10	92.50	0.54	-9.19	-36.35
W WT Harris Blvd (Exit 45B)	48.60	-1.23	-17.28	-13.60	48.70	-3.49	-19.92	-9.51	50.60	-1.19	-20.55	-19.33	46.30	3.67	-13.17	-9.18	48.90	0.20	-17.79	-10.98
W Mallard Creek Church Rd (Exit 46)	104.3	-0.3	-14.9	-3.2	102.3	-0.3	-15.0	-2.6	105.4	-0.4	-16.9	10.0	101.9	2.1	-13.4	-13.0	101.5	-0.5	-13.1	87.8
6/25/2013 from 4 PM - 6 PM	Run 1 (Time) 4:07:20 PM				Run 2 (Time) 4:32:50 PM				Run 3 (Time) 5:13:08 PM				Run 4 (Time) 5:50:45 PM							
Between Exits 41 and 42	90.70	0.33	-0.11	-32.60	90.80	0.22	29.30	-33.31	90.10	1.00	30.30	-31.50	84.90	1.30	32.63	-27.40				
University City Blvd (Exit 43)	94.10	0.96	-10.10	-37.84	90.30	-0.33	-5.65	-36.29	81.40	1.97	4.67	5.01	90.90	0.11	-9.57	-24.37				
W WT Harris Blvd (Exit 45B)	53.40	3.00	-26.97	-21.37	49.30	-0.61	-19.68	-14.00	50.10	1.80	-22.16	-18.08	47.80	2.51	-18.41	-10.59				
W Mallard Creek Church Rd (Exit 46)	104.5	-1.4	-15.0	0.0	102.3	-1.3	-12.6	-1.6	103.6	-0.6	-15.6	-28.7	102.6	1.4	-14.8	-6.0				

Table A-10: Percentage Difference in Travel Times on I-85, Outbound Direction

Location Name	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)	Manual (Sec)	GPS (%)	INRIX (%)	Bluetooth (%)
6/25/2013 from 7 AM - 9 AM	Run 1 (Time) 7:28:12 AM				Run 2 (Time) 8:00:13 AM				Run 3 (Time) 8:29:19 AM				Run 4 (Time) 8:56:12 AM							
Between Exits 41 and 42	88.00	1.14	10.91	-28.43	91.80	-0.87	2.40	-30.50	96.80	0.21	5.17	-35.81	102.30	0.68	-2.83	-43.30				
University City Blvd (Exit 43)	49.20	-4.47	1.63	152.87	48.00	2.08	1.67	148.31	49.50	3.03	9.49	149.15	51.50	0.97	-5.24	137.30				
W WT Harris Blvd (Exit 45B)	89.50	-0.56	-6.82	-51.23	88.90	0.11	-0.79	-53.91	83.70	2.75	6.09	-46.00	88.90	0.11	-9.11	-51.54				
W Mallard Creek Church Rd (Exit 46)	88.0	1.1	83.0	N/A	172.0	-0.6	119.0	-40.4	79.3	0.9	10.7	32.6	87.3	0.8	-1.0	14.4				
6/25/2013 from 11 AM - 1 PM	Run 1 (Time) 11:14:47 AM				Run 2 (Time) 11:37:44 AM				Run 3 (Time) 12:02:13 PM				Run 4 (Time) 12:31:49 PM				Run 5 (Time) 12:54:25 PM			
Between Exits 41 and 42	103.30	1.65	-2.03	-43.79	104.60	0.38	-2.49	-40.54	104.80	0.19	-9.54	-40.27	102.80	0.19	-2.72	-44.52	106.30	1.60	-5.36	-44.31
University City Blvd (Exit 43)	49.60	0.81	0.81	142.72	47.50	1.05	6.53	167.64	48.60	0.82	-4.53	165.58	47.90	0.21	8.14	143.51	49.50	-1.01	2.22	147.70
W WT Harris Blvd (Exit 45B)	93.20	-0.21	-11.16	-50.87	91.20	-0.22	-8.55	-52.01	91.40	0.66	-14.66	-48.41	92.60	0.43	-18.14	-53.06	91.20	1.97	-18.86	-47.71
W Mallard Creek Church Rd (Exit 46)	93.6	-0.6	-9.0	13.2	95.4	-0.4	-8.2	11.5	93.6	0.4	-20.3	4.8	96.7	0.3	-21.0	5.4	93.7	1.4	-19.7	11.2
6/25/2013 from 4 PM - 6 PM	Run 1 (Time) 4:07:20 PM				Run 2 (Time) 4:32:50 PM				Run 3 (Time) 5:13:08 PM				Run 4 (Time) 5:50:45 PM							
Between Exits 41 and 42	104.40	-0.38	-5.36	-43.69	101.10	0.89	-5.84	-39.79	119.50	0.42	-14.81	-49.88	103.10	0.87	-0.10	-40.24				
University City Blvd (Exit 43)	47.60	2.94	3.78	210.69	44.90	0.22	2.00	367.84	47.30	-0.63	8.25	213.70	46.50	-1.08	11.40	156.60				
W WT Harris Blvd (Exit 45B)	90.70	1.43	-21.72	-51.46	85.10	1.06	-15.16	-43.31	91.20	0.88	139.69	-52.50	89.80	-0.89	80.62	-9.09				
W Mallard Creek Church Rd (Exit 46)	97.7	0.3	48.2	9.7	189.2	0.4	64.4	-44.1	765.8	0.5	-26.6	-86.5	581.1	0.2	15.2	-83.2				

COMMERCIAL REMOTE SENSING & SPATIAL INFORMATION (CRS & SI) TECHNOLOGIES PROGRAM FOR RELIABLE TRANSPORTATION SYSTEMS PLANNING: VOLUME 2 - COMPARATIVE EVALUATION OF TRAVEL TIME RELATED PERFORMANCE MEASURES



Final Report No. RITARS-12-H-UNCC-2

Prepared for
The Office of the Assistant Secretary for Research and Technology (OST-R)
United States Department of Transportation (USDOT)

COMMERCIAL REMOTE SENSING & SPATIAL INFORMATION (CRS & SI) TECHNOLOGIES PROGRAM FOR RELIABLE TRANSPORTATION SYSTEMS PLANNING: VOLUME 2 - COMPARATIVE EVALUATION OF TRAVEL TIME RELATED PERFORMANCE MEASURES

Final Report # RITARS-12-H-UNCC-2

Prepared for

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16. Abstract

Travel time reliability is commonly used in reference to the level of consistency in transportation service for a trip, corridor, or route. They range from travel time percentiles, to travel time indices and variance based measures. However, most of these measures cannot be used to compare the performance of two different segments with varying characteristics. Also, each of the measures computed as travel time percentiles, travel time indices and variance based measures may yield different outcomes. All these travel time measures are computed by time-of-the-day and day-of-the-week (one dimensional), while none of these measures incorporate the effect of variation in travel times by week-of-the-year. This study focused on 1) evaluating relationship between several travel time related performance measures, 2) establishing and identifying suitable performance measure based on application and purpose, and, 3) demonstrating the use of a multi-dimensional reliability performance measure. The results indicate that average travel time and buffer time index (BTI) are correlated to percentile based travel time measures and travel time indices, respectively. The performance measures based on travel time variances can be used for before and after studies, while reliability indices such as BTI, planning time index (PTI), travel time index (TTI), λ skew, and λ variance can be used to evaluate the condition of a facility (level of congestion or reliability) and compare the performance of one link with the other link. The proposed macro-level measure of reliability (Cronbach's α) helps evaluate the level of consistency of travel times from a multi-dimensional perspective and is found to be a better estimator of expected travel times as compared to the traditional reliability performance measures.

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EXECUTIVE SUMMARY

Urban transportation networks are regularly plagued with congestion problems. Travel time is an important parameter of the transportation system. Link-level congestion problems of transportation systems are primarily expressed as travel time. The variation in travel time could be due to different factors such as the motorist's characteristics, vehicular characteristics, and road characteristics. It also varies with the time-of-the-day (ToD), the day-of-the-week (DoW), and the week-of-the-year (WoY).

Practitioners and researchers have proposed and used the concept of reliability to assess transportation system performance in recent years. It is the consistency, dependability, or change in the travel time during a particular ToD or different days of the week. It is commonly used in reference to the level of consistency in transportation service for a trip, corridor, mode or route in terms of its travel time. Travel time reliability (or index or variability) is considered as the most viable performance measure though most agencies currently use volume-to-capacity ratio for ranking and prioritization of transportation projects. The possibility of capturing dynamic travel time data from private sources such as INRIX, TomTom and HERE opens many pragmatic avenues to better compute reliability related performance measures for transportation planning applications and project prioritization.

Typically, reliability is viewed by motorists in relation to their past experience and helps them assess their expected future trip travel time. Reliability is, therefore, a measure of quality of service the system offers its motorists. In an unreliable system, the motorist cannot assess his/her trip duration length (in time) and, hence, would not be in a position to rely on any schedule that he/she makes. With increasing congestion levels in most of the urban areas, there is a need to at least be aware of when and where the congestion occurs, thereby, enabling a motorist to estimate the probable travel time as closely as possible (or make other travel related decisions). This is most important and commonly observed with the freight carriers that have their travel schedules already made before the trip actually begins. Hence, it is of utmost importance that system performance is also measured on the basis of reliability. These reliability measures range from travel time percentiles, to travel time indices and variance based measures.

Traditional indicators of reliability range from travel time percentiles to travel time indices and variance based measures. Examples include 85^{th} percentile travel time, planning time (PT), buffer time (BT), buffer time index (BTI), planning time index (PTI), travel time index (TTI), λ skew, and λ variance. These measures may yield different outcomes that could be applicable for different purposes (quantify level of congestion or reliability, before and after studies, or compare one link with another link for prioritization). Since all these measures are evaluated for a single arrayed dataset, they only measure the reliability in one dimension. However, travel time variation due to congestion depends on ToD, DoW and WoY (involves multiple factors or dimensions). The one dimensional measures, while addressing the reliability of a link, confine themselves to the trips of a given ToD and DoW.

This study focused on 1) evaluating relationship between selected travel time, travel time percentile, index and variance based performance measures, 2) establishing and identifying suitable performance measure based on application and purpose and 3) demonstrating the use of a multi-dimensional performance measure.

INRIX travel time data of Charlotte, North Carolina, for the years 2009 and 2010, comprising about 295 and 311 Traffic Message Channel (TMCs) codes (links), respectively were used in the current research. Most reliable travel time values for each link were determined based

on their associated error, while also classifying the link-level performance into different levels of service using the reliability scores that are evaluated in this research.

The reliability measures considered in this research are free flow travel time, median travel time, 85th percentile travel time, BT, PT, and reliability indices such as BTI, PTI, TTI, travel time variance, λ skew, and λ variance. The methodology was carried out in four different steps to examine the relationship between travel time and the reliability measures. They are: data collection, selection of reliability measures, computation of reliability measures, and statistical analysis. Correlation analysis was performed considering selected days and time periods.

Results obtained from statistical analysis indicate that average travel time is not correlated with the reliability indices except with the BT for almost all the cases examined in this research. However, it is correlated to all travel time and travel time percentile related measures. BT is correlated to most of the measures, while BTI is correlated to most of the reliability related measures. From these findings, average travel time can be used to assess link performance or for before and after studies. BTI can be used for before and after studies as well as for the comparison of two different links. Overall, performance measures based on travel time variances can also be used for before and after studies and for comparing two different links with similar characteristics.

The proposed reliability measure, Cronbach's α, to assess reliability of links in the transportation network acts as a macro-level measure of reliability that evaluates the level of consistency of travel times. The proposed reliability measure was found to be a better estimator of expected travel times when compared to the performance measures such as BTI and PTI, which are often evaluated for fixed criteria (say, ToD). This is because the proposed macroscopic measure evaluated reliability not only for a ToD over the year but also for a WoY over the ToD and using both 85th percentile travel times as well as average travel times from the historical data. The reliabilities that are evaluated at link-level helps identify the most unreliable links in the network. Overall, this measure could be used to indicate level of reliability, durations as well as compare performance of various links in the transportation network.

Categorizing trips using their weekday/weekend information helps in identifying the trends of the travel times corresponding to the trips. However, using the 85th percentile travel times to compute Cronbach's α were found to be over-estimating the trip durations, whereas the WoY was found to be one of the main factor influencing travel times.

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CHAPTER 1: INTRODUCTION

Traffic congestion, in general, reduces the capacity of the roadway and makes the traffic condition unstable. Congestion due to regular commute traffic during morning and evening peak hours is referred to as recurring congestion. It is generally measured in terms of travel time, travel time per mile, travel delay, variation in travel time or volume-to-capacity ratio, and used in long-range transportation planning decisions by Strategic Transportation Planning Offices and regional planning agencies. These metrics also help quantify intensity, duration and extent of congestion and assist in the development of congestion management plans. Incidents during these peak hours further deteriorate operational performance on roads (reduce speed and lower freedom to maneuver).

As congestion increases, travel time reliability (or reliability, in general) becomes an increasingly important attribute for motorists of transportation network. Most motorists experience and remember more than a simple average throughout a year of commute. Their travel times vary greatly from day-to-day, and they remember those few bad days they suffered through unexpected delays. A 1997 survey showed that reliability, therefore, is one of the most important factor for route choice, making it either the most or second most important reason for choosing primary commute routes (Abdelwahab and Abdel-Aty, 2001). Route-choice laboratory experiments and computer simulations conducted by Avineri and Prashker (2005) indicated that the higher the variance in travel time, the lower is motorists' sensitivity to travel time differences. In another study, results from preference data collected in Barcelona, Spain showed that reliability is valued on average 2.4 times more than travel time savings (Asensio and Matas, 2008). A large proportion of the unreliability experienced by motorists can be attributed to incident related disruptions (Uniman et al., 2010).

Reliability, in general, measures the extent of the unexpected delay. It is the consistency or dependability in travel times, as measured from day-to-day and/or across different times-of-the-day (FHWA, 2012). Ebeling (1997) defined reliability as the probability that a component or system will perform a required function for a given period of time when used under stated operating conditions. It is the probability of a non-failure over time. Ebeling (1997) further states that the definition must be made specific by providing an unambiguous and observable description of a failure (example, traffic speed is less than 20 mph on a 55 mph speed limit urban expressway), including the unit of time over which failure will be evaluated (example, evening peak hour). Reliability could also be defined as the operational consistency of a facility over an extended period of time (Shaw, 2000). It is the probability of a device performing its purpose adequately for the period of time intended under the stated operating conditions.

The reliability of a link, corridor or the transportation road network could also be defined as an ability to provide an acceptable level-of-service (LOS) to the traveler under stated environmental and operational conditions during a given period. It is significant to many transportation system users; whether they are motorists, transit riders, freight shippers, or even air travelers. Personal and business travelers value reliability because it allows them to make better use of their own time. Shippers and freight carriers require predictable (reliable) travel time information to remain competitive.

The distribution of travel times over a period of time are used to compute statistical parameters such as mean, median, mode, standard deviation, buffer time (BT), planning time (PT), travel time index (TTI), buffer time index (BTI), and planning time index (PTI). These parameters are indicators of the degree of variability of single category trips on a link. In this

approach, travel time variation is the degree of variability based on trip history data. Likewise, in a real-time sense, reliability can be considered as motorist experiencing the same trip length (duration-wise) over and over again, i.e., a trip being taken now is compared to some sort of pre-set standard travel time (by the motorist). If a large number of repeated trips on a link fall within the previously observed trip lengths, expected based on any of the characteristics of the trip such as time-of-the-day (ToD), day-of-the-week (DoW), or week-of-the-year (WoY), it is said to be a reliable link; no otherwise. So, if there is no trend seen or no reliable group observed in any way, it becomes difficult to have an estimate of the probable travel time of the future trip. Reliability is, therefore, an important measure that could help assess health and efficiency of transportation system in a region.

1.1. Need for Research

One of the key objectives of the recent Moving Ahead for Progress (MAP-21) legislation is to establish a performance-based program to provide a means for more efficient investment of federal transportation funds and improving transportation investment decision making through performance-based planning and programming (FHWA, 2012).

Practitioners and researchers have used a wide range of definitions for reliability and developed several metrics to report it. These measures range from travel time measures to those indicating severity of congestion, level of dependability, and relative level of dependability. However, limited literature exists in the body of knowledge on the relationship between the different travel time and reliability measures. These measures may yield different results. The selection of reliability measure could depend on the type of transportation study (example, assess the level of congestion, compare before-after constructing a project, or rank sections along a corridor to allocate funds for improvement). There is a need to research and examine the relationship between travel time and reliability measures, and, recommend suitable measures for different purposes.

Any trip on a link has its corresponding ToD, DoW, and WoY. Each trip has an associated travel time which is a function of these variables. Here, ToD, DoW, and WoY can be treated as the independent variables and travel time as the dependent variable. The variability of travel times can be studied by keeping either one or two of these independent variables fixed (unchanged) to reduce the number of dimensions. For example, BTI is a reliability index that is often evaluated keeping ToD and DoW as constants, making it a one dimensional measure i.e., only one variable (in this case WoY) changes and the index for the associated travel times is evaluated. In this case, BTI can only be used to address the reliability of travel times on a link for a given ToD and DoW. However, if one has to compare the reliabilities of two different days of the week, or reliabilities of Mondays over weekdays, it is not possible using the traditional BTI measure. This inability to compare the reliabilities of different groups limits these indices from determining the most reliable groups and the most reliable travel times. A two-dimensional measure can address this limitation by allowing comparison of different groups to determine reliable groups. There is, therefore, a need to explore and illustrate the working two-dimensional measure to quantify reliability.

1.2. Research Objectives

The key objectives of this research are:

1) to examine the relationship between travel time, travel time percentile, index and variance related reliability measures, and, recommend suitable measures for different purposes, and,
2) demonstrate the working of multi-dimensional reliability measure (Cronbach's α) that helps compare different time period groups to determine reliable groups.

1.3. Organization of this Research

This research report is organized as follows. A review of past literature, underlying methods and their limitations are discussed in Chapter 2. An evaluation of relation between various travel time and reliability measures are discussed in Chapter 3. The description of study area, methodology and illustration of the proposed two-dimensional performance measure (Cronbach's α) are discussed in Chapter 4. Conclusions and directions for future research are presented in Chapter 5.

CHAPTER 2: LITERATURE REVIEW

Several researchers have focused on the concept of travel time reliability in recent years. A detailed review of literature on (1) various travel time reliability measures, (2) travel time and reliability as a performance measure, (3) LOS based on reliability, and, (4) future of travel time reliability in transportation sector is presented next.

2.1. Travel Time Reliability Measures

Literature documents the use of several terms such as connectivity reliability, capacity reliability, travel demand satisfaction reliability and travel time reliability. The connectivity reliability is defined as the probability of network nodes being connected or disconnected (Iida and Wakabayashi, 1989). Later due to the binary limitation of this approach (Recker et al., 2005), various other indicators such as socio-economic impact of unreliability and travel demand reduction reliability (Nicholson and Du, 1997), capacity reliability (Chen et al., 2002), travel demand satisfaction reliability (Lam and Zang, 2000) and travel time reliability (Asakura and Kashiwadani, 1991) were proposed. Among all these reliability indicators, travel time reliability is considered as the most superior measure by both transportation planners and system users.

Since the inception of the concept of travel time reliability, there has been increased research to explore methods for travel time reliability measurement. There are essentially two types of approaches (heuristic and statistical) involved in the measurement of travel time reliability. Asakura and Kashiwadani (1991) defined travel time reliability as the probability of successfully completing a trip for a given origin destination pair within a given interval of time at a specified level. The main performance indicators were found to be specified travel time and specified network service. Along the same lines, various mathematical models have been developed to measure travel time reliability of a transportation system (Chen et al., 2002). Abdel-Aty et al. (1995) and Chen et al. (2003) studied the effect of including travel time variability and risk-taking behavior into the route choice models, under demand and supply variation, to estimate travel time reliability. Haitham and Emam (2006) developed a methodology to quantify degraded link capacity and varying travel demand, eventually to estimate travel time reliability and capacity reliability. They estimated the expected travel time for a degraded link to be lesser than the free flow travel time for the link with a specific tolerance level. This tolerance pertains to the desired LOS for the link even after its capacity has degraded.

Heydecker et al. (2007) proposed a travel demand satisfaction ratio which can be used to evaluate the performance of a road network. They also found that the demand satisfaction ratio can be equivalent to the travel time reliabilities in some conditions. Based on the traditional user equilibrium principle, Chen et al. (2010) proposed a multi-objective reliable network design problem model to account for the travel time reliability and capacity reliability in order to determine the optimum enhancement of the link capacity. Florida Department of Transportation (DOT) used the median of travel time plus some percentage of median travel time (residual or error term) to estimate the travel time during any period of interest (FDOT, 2000).

The Federal Highway Administration (FHWA) defined travel time reliability to be the consistency in travel time on a daily/timely basis (FHWA, 2006). The performance indicators introduced are 95^{th} percentile travel time, BTI, and PTI. These measures are mainly derived from the travel time distribution. Clark and Watling (2005) proposed a technique for estimating the probability distribution of total network travel time, which considers the daily variations in the travel demand matrix for the transportation network. Differences and similarities in

characteristics (average travel time, 95th percentile travel time, standard deviation, coefficient of variation, and BTI) were investigated for one radial route by Higatani (2009).

Cambridge Systematics Inc. (2005) suggested various indices regardless of the source or the type of variability, which are commonly divided into statistical, buffer measures, and tardy trip indicators. Statistical methods, such as travel time window and percent variation (shown in equations 2.1 and 2.2) focus on estimating standard deviation of travel times and comparing it to the average travel time.

$$\text{Travel Window} = \text{Average Travel Time} \pm \text{Standard Deviation} \quad \text{Eq. 2.1}$$

$$\text{Percent Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \text{ x } 100\% \quad \text{Eq. 2.2}$$

Though these statistical measures provide the extent of unreliability to professionals, it is difficult for individuals to apply the concept of standard deviation to their individual travel time. In addition, the variation due to different events is difficult to comprehend for the individuals.

Tardy trip indicators, which include percent of unreliable trips and misery index, are other means to evaluate the variability in the travel time. The percent of unreliable trips is simply evaluated as the percent of trips with higher than acceptable travel times. The misery index is computed as the average travel time subtracted from travel time from the top 20% of trips divided by average travel time.

$$\%\text{ on Time} = \text{Percent Trip Times} < [1.1 * \text{Mean Time}] \quad \text{Eq. 2.3}$$

$$\text{Misery Index} = \frac{\text{Average Travel Time for the Longest 20\% of Trips} - \text{Average Travel Time}}{\text{Average Travel Time}} \quad \text{Eq. 2.4}$$

Lyman and Bertini (2008) and FHWA (2013) defined frequency of congestion as the frequency when congestion exceeds some expected threshold. This index is typically expressed as the percent of days or time that travel times exceed "X" minutes or travel speeds fall below "Y" mph. In case continuous traffic data is available, the frequency of congestion measure is relatively easy to compute. It is typically reported for weekdays during peak traffic periods.

The standard deviation is a widely employed measurement of variability or diversity in statistics and probability theory. It shows variation or "dispersion" from the average (mean or expected value) and is sometimes used as a proxy for other reliability measures. It is a convenient measure when calculating travel time reliability using classical or statistical models (Dowling et al., 2009). The standard deviation treats both late and early arrivals with equal weight while the public cares much about late arrival. Therefore, it cannot be related to everyday commuting experiences.

$$\text{Standard Deviation} = \sqrt{\frac{\Sigma (\text{Each Value in the Data Set} - \text{Average Value in the Data Set})}{\text{Number of value in the Data Set}}} \quad \text{Eq. 2.5}$$

The coefficient of variation is a ratio of standard deviation to the mean. It also has the same disadvantages as the standard deviation.

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Average Travel Time}} \quad \text{Eq. 2.6}$$

The standard deviation to average value combined in a ratio is referred to as percent variation in the 1998 California Transportation Plan (Guo et al., 2010). This is the form of the statistical measure, coefficient of variation. Thus, mathematically, it has the same characteristics as the coefficient of variation. Though the percent variation is expressed as a percentage of average travel time, it is easily understandable (Pu, 2011).

$$\text{Percent Variation} = \frac{\text{Standard Deviation}}{\text{Average Travel Time}} \times 100\% \quad \text{Eq. 2.7}$$

The failure rate or percent of on-time arrival estimates the percentage of time that a traveler arrives on time based on an acceptable lateness threshold. The threshold travel time to determine an on-time arrival ranges from 110% to 113% of average travel time.

$$\text{Failure rate} = 100\% - \text{Percent of On-Time Arrival} \quad \text{Eq. 2.8}$$

Florida DOT uses a percentage of the average travel time in the peak to estimate the limit of the acceptable additional travel time range (FDOT, 2014). The sum of the additional travel time and the average travel time define the expected travel time and the travel times longer than this expected travel time would be termed as "unreliable". However, this calculation method has the disadvantage of using travel time rather than travel rate, while travel rate variations provide a length-neutral way of grading the system performance providing the provision of easy transmission to travelers (Lomax et al., 2003).

$$\text{Florida Reliability Statistic (\% of Unreliable Trips)} = 100\% - (\text{Percent of trips with travel times greater than expected}) \quad \text{Eq. 2.9}$$

In addition to the statistical methods of estimating travel time reliability, Elefteriadou and Cui (2006) proposed econometric modeling. They developed linear regression models to estimate average travel time for scenarios with different combinations of weather, crashes, congestion and work zones.

Texas Transportation Institute (2005) suggested a threshold of 10% higher than the average travel time (or travel rate) for travel time reliability. However, the 10% late arrival has the disadvantage of being relatively conservative for some applications. Clark and Watling (2005) used the probability distribution of the actual values of the performance measure to define unreliability. The planning state occurs when the performance measure equals the mode of around 1. The critical value is defined as a tolerance of 400% above the performance measure value in the planning state, yielding to a critical value of 5. Afterwards, the unreliability is defined, for instance, in terms of the probability of exceeding the critical value Pr ($M > 5$), i.e., the area under the curve in the range labeled "degraded performance" (Figure 1). Therefore, in percentage terms, the reliability is

$$\rho = (1 - \Pr(M > 5)) \times 100\% \quad \text{Eq. 2.10}$$

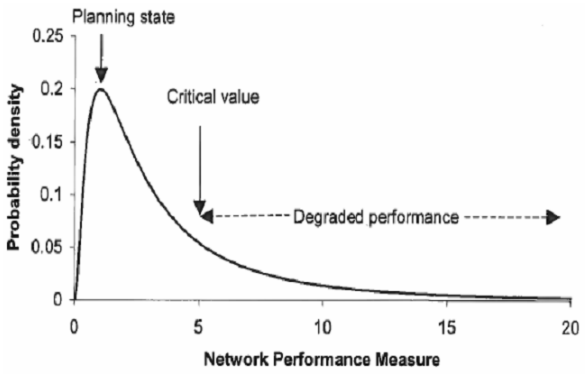


Figure 1: Performance Measure Distribution (TTI, 2005)

Among all measures of travel time reliability, BTI and PTI are standardized and used to compare two different roadway systems. On the other hand, measures such as BT and PT are incomparable between different systems. These indices are used to compare the before-after condition of a same roadway system (National Center for Transit Research - NCTR, 2010). Van Lint and Van Zuylent (2005) stated that the travel time reliability relates to properties of the day-to-day travel time distribution as a function of ToD, DoW, month-of-the-year, and external factors such as weather, incidents and road works.

NCHRP (1998), TranSystems (2005), and AASHTO (2008) defined the reliability as standard deviation of travel time, on-time performance of freight systems, and probability of on-time travel, respectively. TT_{95} and TT_{90} are 95th and 90th percentile travel times, respectively, which are the first and second worst travel times over a month. TT_{95}, which is defined as PT (Wakabayashi et al., 2012), is more general because it shows the delay for 1 day out of the 20 work days in a month and is two times the standard deviation of a normal distribution (Wakabayashi, 2010). TT_{Avg} is the average of travel time. PTI represents the total required travel time for an on-time performance, while the BT represents the required additional time for an on-time performance (Sisiopiku and Islam, 2012). $TT_{free\ flow}$ is free flow travel time, which is 15th percentile travel time during weekdays off-peak hours (Wakabayashi et al., 2012; Tu et al., 2007).

The difference between 90th and 10th percentile travel time is considered as the measure of travel time uncertainty, which is defined by Tu et al. (2007) as travel time variability index. λ skew and λ Variance are defined by van Lint et al. (2004) and Bogers et al. (2008) as other measures of reliability. TT_{85}-TT_{15}, TT_{80}-TT_{20}, and TT_{70}-TT_{30} are other indices to define the travel time reliability and are useful measures for both transportation system operators and users (Wakabayashi, 2010). Wakabayashi (2010) defined $P(TTavg + ATTV)$ and $P(TTavg - DTTR)$ in which $P(t)$ is the function of computing percentile value of travel with time t, $TTavg$ is average travel time, $ATTV$ is acceptable travel time variation, and $DTTR$ is desired travel time reduction.

In summary, reliability indices are travel time percentiles (example, PT), ratios of two travel times or travel time percentiles (example, PTI and TTI), differences between two travel times or travel time percentiles (example, BT, travel time variability, $TT_{85} - TT_{15}$, $TT_{80} - TT_{20}$ and $TT_{70} - TT_{30}$), ratios of difference between two travel times and a travel time percentile (example, BTI and λ_{var}), or ratios of differences between pairs of travel times (example, λ_{skew}). Selected travel time reliability measures are summarized in Table 1 (Pulugurtha and Duddu, 2014).

Table 1: Summary of Reliability Measures (Pulugurtha and Duddu, 2014)

Index	Measure / Equation	Index	Measure / Equation
NCHRP (1998) Definition	Std. Dev. of travel time	λ skew (van Lint et al., 2004)	$(TT_{90} - TT_{50})/(TT_{50} - TT_{10})$
AASHTO (2008) Definition	On-time performance	λ variance (Bogers et al., 2008)	$(TT_{90} - TT_{10})/TT_{50}$
TranSystems Definition (2005)	Probability of on-time performance	Variability (Wakabayashi, 2010)	TT_{85}-TT_{15}
Buffer Time (BT) (Lomax et al., 2004)	$TT_{95} - TT_{Ave}$	Variability (Wakabayashi, 2010)	TT_{80}-TT_{20}
Buffer Time Index (BTI) (Lomax et al., 2004)	$\frac{TT_{95} - TT_{Avg}}{TT_{Avg}} \times 100$	Variability (Wakabayashi, 2010)	TT_{70}-TT_{30}
First worst travel time over a month (Wakabayashi et al., 2012)	TT_{95}	Acceptable Travel Time Variation Index (Wakabayashi, 2010)	$P(TTavg + ATTV)$
Second worst travel time over a month (Wakabayashi et al., 2012)	TT_{90}	Desired Travel Time Reduction Index (Wakabayashi, 2010)	$P(TTavg - DTTR)$
Planning Time (PT) (Wakabayashi et al., 2012)	TT_{95}	Travel Time Index (TTI) (Lyman and Bertini, 2008)	$\frac{TT_{Ave}}{TT_{free\ flow}}$
Planning Time Index (PTI) (Sisiopiku and Islam, 2012)	$\frac{TT_{95}}{TT_{free\ flow}}$	Frequency of Congestion (Lyman and Bertini, 2008)	Percent of days/periods that are congested
Travel Time Variability (TTV) (Tu et al., 2007)	$TT_{90} - TT_{10}$		

Overall, there are two ways of defining the travel time reliability. Firstly, it could be based on the definition of failure where the reliability is defined as the probability of an on-time performance. Using this definition, it is possible to track the reliability over time and evaluate the

condition of the facility for agencies (Elefteriadou and Cui, 2006). Secondly, it could be based on the variability of travel time (i.e., unpredictability of travel times from the users' viewpoint), using some measures of central tendency (example, mean or median) and a measure of dispersion (example, standard deviation or acceptable additional time), which will make a sense for users (Elefteriadou and Cui, 2006).

2.2. Travel Time and Reliability as Performance Measures

A review of literature on travel time and reliability as performance measures is presented in this section.

2.2.1. Travel Time as Performance Measure

Many researchers have focused on travel time related studies in the past. Rudnicki (1999) proposed and used equivalent travel time of passengers as a synthetic performance measure to evaluate the operation of public transportation in urban areas. Both physical relationships and subjective assessment were taken into account in computing the measure, which is the weighted average sum of different times.

Lomax and Schrank (2010) performed research on travel time performance measures and concluded that total travel time can provide additional explanatory power to a set of mobility performance measures. Nayyar (2013) concluded that there is a low difference in calculated and observed travel times resulting from two approaches of data collection, one is from highway sensor data and the other one is from smart phone application.

Williams et al. (2013) worked on the validation of travel time estimation method and evaluation of various reliability measures using data for five study segments. Their study used INRIX data for the years 2010 and 2011. Correlation analysis was performed between the travel times and reliability measures taken for 15-minute interval data. Skew statistic and semi-standard deviation were observed not correlated with the average travel time. Therefore, one or both measures were recommended for use in internal performance analysis. While this recommendation was consistent with Strategic Highway Research Program (SHRP) recommendation, it was inconsistent with the FHWA recommendation.

A study on freeway travel time estimation using data from 700 existing fixed traffic sensors in St. Louis, Missouri was carried by Yao-Jan et al. (2013). The results obtained from MATLAB-based system and a Microsoft Excel VBA-based tool were then verified using travel time data collected using Bluetooth-based method and a video-based manual-vehicle-matching method.

Philip et al. (2014) concluded that the total peak period travel time gives extra information on the set of mobility performance measures, reducing the gaps between the traditional delay based measurement and accessibility.

2.2.2. Reliability as Performance Measure

Zehen-Ping et al. (1996) proposed a model to improve system reliability and to identify critical components for a simple network. The practical measures of reliability were also described along with the algorithms for solving the reliability model. This model could get exact solutions only for very small or regular networks. The best approach described to estimate the system reliability is approximate solution and recursive algorithm which shows how the component and system reliability are connected.

Noland (1997) developed a model to determine optimal home departure times with a supply-side congestion model of a highway facility and got the results which suggested that costs of commuting can be reduced by polices suggested to reduce travel time variance and not just travel time. The analyses showed the behavioral adjustments that commuters make before entering traffic in response to given levels of uncertainty. These results are applicable to some very common situations as the route choice problem or interactions in a network and mode choice were not considered during analysis.

Chen et al. (2002) proposed capacity reliability index which includes connectivity reliability and yields travel time reliability. A structure was developed which included network equilibrium models, sensitivity analysis and reliability, and uncertainty analysis. These were used to obtain numerical results to demonstrate feasibility of reliability evaluation procedure. Suggestions were made for further research so as to attain significant and practical results.

Clark and Watling (2005) proposed a method for estimating the probability distribution of total network travel time considering normal day-to-day variations in the travel demand matrix over a road traffic network. They proposed a solution method based on a single run of a standard traffic assignment model. Moments of the travel time distribution were computed using an analytic method based on the multivariate moments of the link flow vector. A flexible family of density functions was fitted to these moments. The researchers also discussed how the resulting distribution in practice could be used to characterize unreliability. They found the method to be effective in identifying sensitive or vulnerable links and for the examining the impact on network reliability of changes to link capacities (Clark and Watling, 2005).

Sanchez-Silva et al. (2005) proposed a model to optimize the allocation of resources based on the operational reliability of transport network systems. This model provides a very useful structure for optimizing the assignment of resources to enhance the reliability of any transport network system. To compute transportation system reliability of a network, they adopted a method which is based on probabilistic view. In this method, the state of the infrastructure and the behavior of the network users were considered as two main elements. The first element, infrastructure, is based on the state of the network i.e., the relationship between the failure and repair rates of every link of the network and these rates are directly related to physical characteristics of the road such as condition of the road, or frequency and size of landslides. The second element, behavior of road users, is known by modeling the decision making process of the individual to take a route between any two nodes.

Lui et al. (2005) examined time-dependent effects on traveler's route choice decisions by assuming that travelers' tastes toward the travel time and its reliability vary with time. They have adopted a mixed-logit formulation of route choice behavior as a function of travel time, reliability, and cost. Their study compared time-dependent traffic volume data from loop detectors with route choice model to identify the coefficients using Genetic Algorithms. The results indicated that travel-time savings may be more important than uncertain travel time when departure time is close to such time constraints as work-start time under the time-dependent formulation.

According to Tu et al. (2005), weaving sections can lead to certain variations in travel time due to intense lane changing maneuvers and complex vehicle interactions. The length of the weaving section is the primary factor for such variability. Therefore, the researchers investigated the relationship between them based on both a simulation approach and empirical data. Both procedures indicate a relationship between a certain weaving section length threshold and travel

time variability increase. The implications call for possible control applications to reduce the travel time variability in the short weaving sections.

Van Lint and van Zuylen (2005) proposed many different aspects of the day-to-day travel time distribution as indicators of reliability. Both mean and variance of a distribution tend to obscure important aspects of the distribution under specific circumstances. They argued that both skew and width of this distribution are relevant indicators for unreliability. They proposed two reliability metrics based on three characteristic percentiles (10^{th}, 50^{th}, and 90^{th} percentiles) for a given route and ToD-DoW period. High values of either metric indicate high travel time unreliability, while the weight of each metric on travel time reliability may be application or context specific. These metrics can be used to construct reliability maps in order to visualize the unreliability of travel times for a given ToD-DoW period and help identify ToD-DoW periods in which congestion will likely set in (or dissolve). The overall process can identify the uncertainty of start and end; and, hence, length of morning and afternoon peak hours. The metrics can be used to predict travel time unreliability if combined with a long-term travel time prediction model and also may be used in discrete choice models as explanatory variables for motorist uncertainty.

Nam et al. (2005) expressed reliability in terms of standard deviation and maximum delay measured based on triangular distribution. The researchers used the multinomial and Nested Logit models to estimate the value of time and value of reliability. They found that reliability is an important factor affecting mode choice decisions. As reliability has higher values than that of time, the policy to increase travel time reliability has more benefit than to reduce the travel time at the same level of improvement.

According to Al-Deek and Emam (2006), travel time reliability captures the variability experienced by individual travelers and can indicate the operational consistency of a facility over an extended period. A roadway segment's reliability is considered 100% if its travel time is less than or equal to the travel time at the posted speed limit for that segment. They only considered the weekdays as weekends had different peak periods. The freeway corridor consists of a collection of links arranged and designed such that they achieve desired functions with acceptable performance and reliability. However, the relationship between the freeway corridor system reliability and its links' reliability is often misunderstood. For example, all the links in a system having 95% reliability at a given time does not mean the overall reliability of the system is 95% for that time. This emphasizes the need to consider travel time reliability at the link-level.

The prevailing traffic information that depicts the current network conditions is generally provided to trip makers to avoid recurrent and non-recurrent congestion. Dong et al. (2006) stated that route guidance based on prevailing trip times could be counterproductive. Anticipatory information is derived from forecasts of network sites in order to consider the social and temporal changes in traffic conditions. They examined these values with predictive travel time calculated using both analytical and simulation based approaches and concluded that predictive travel time is reliable.

Elefteriadou and Xu (2007) developed models for estimating the travel time reliability on freeway based on four factors (congestion, work zones, weather, and incidents) that may affect travel time. Sumalee and Watling (2007) proposed a partition-based method to evaluate the transport network from the viewpoint of travel time reliability after any disaster. The proposed algorithm is expected to classify the network states into reliable, unreliable, and un-determined partitions. Each reliable and/or unreliable state can be used to determine a number of other reliable and/or unreliable states without evaluating all of them with an equilibrium assignment

procedure by postulating the monotone property of the reliability function. A cause-based failure framework was also proposed to represent dependent link degradation probabilities and tested with a medium size test network to illustrate the performance of the algorithm.

Shao et al. (2007) proposed a travel time reliability-based traffic assignment model in order to identify the rain effects on risk-taking behaviors of travelers considering day-to-day demand fluctuations and variations in travel time. A Logit-based stochastic user equilibrium framework was used to incorporate travelers' perception errors on travel time and risk-taking behavior on path choices into the model.

Pulugurtha and Pasupuleti (2007, 2010) estimated travel time using the Bureau of Public Roads (BPR) equation and travel delays due to crashes on each link. The travel times and travel delays due to crashes were combined to evaluate the reliability of the link. The reliability was computed in two different ways. The first one was based on percent variation in travel time, while the second integrated percent variation in travel time and the impact of crashes on travel time. The affect of crashes associated to non-recurring congestion component was observed to vary by ToD.

Bertini and Lyman (2007) used archived ITS data to examine the use of measured travel time reliability indices to improve the real-time transportation management and traveler information. Many reliability measures were tested to find out the ways to improve the communication about reliability to the users, so that, the travelers can make the most appropriate usage of the system for their purposes. This helps improve the health of the whole transportation system.

Wasson et al. (2008) used Bluetooth detectors to collect Media Access Control (MAC) addresses in order to evaluate travel times through address matching. The study was conducted on arterials and freeways in Indianapolis to estimate travel times. Due to the effect of traffic signals and the noise that is introduced when motorists divert from the network, data from arterial highways showed a significantly larger variance compared to data from the freeways.

Lyman and Bertini (2008) examined the use of measured reliability indices for the improvement of real-time transportation management and traveler information using archived Intelligent Transportation System (ITS) data. They used the buffer index to prioritize freeway corridors and concluded that Metropolitan Planning Organizations (MPO) should use travel time reliability by incorporating it as a system-wide goal, evaluating roadway segments according to travel time reliability measures, and prioritizing the capacity expansion of roadway segments using these measures.

Tu et al. (2008) proposed a new analytical formula to express travel time unreliability in which the travel time unreliability is computed as the sum over the products of the consequences (variability or uncertainty) and corresponding probabilities of traffic breakdown (instability). The proposed travel time reliability model is considered as a function of a variety of conditional factors under certain circumstances such as road characteristics, traffic control measures, prevailing traffic state (congested or not), and possibly external factors (weather and luminance). Empirical data were used to validate and calibrate the model. They found that with the increase in inflows, both the probability of traffic breakdown and travel time unreliability increase.

Chang (2010) identified seven factors which cause unreliable travel time and used two evaluation requirements (measurements and valuations) to estimate travel time reliability. Korean data of road and rail usage was taken to calculate unit values for the requirements. The travel time values were estimated using logit-based choice model to obtain practical estimates for transport appraisal.

Uniman et al. (2010) explored the potential of using automated fare card data to quantify the reliability of service as experienced by passengers of rail transit systems. A set of service reliability measures were developed using the distribution of passenger journey times from fare card data to evaluate transit service. The authors indicated that a large proportion of the unreliability experienced by passengers can be attributed to incident related disruptions and sizable improvements in overall transit service quality can be attained through reliability improvements.

Haseman et al. (2010) evaluated travel time delays at work zones using Bluetooth detectors. The study involved collection of 1.4 million travel time records over a 12 week period for a rural interstate highway work zone along I-65 in northwestern Indiana and compared with traditionally measured travel time profiles under both incident and non-incident conditions. Results indicate that 30% of observed probes took alternate routes upon implementation when compared to negligible percent of probes taking alternate route through self-guidance. They concluded that real-time data acquisition could help 1) improve trip planning, both before and during their trip, 2) evaluate alternative maintenance of traffic techniques and identify best practices, 3) improve work zone queue forecasts, 4) assess the relationship between crashes and work zone queuing, and, 5) enable future contracts to include innovative travel time reliability clauses. However, additional studies are warranted to formally test the hypothesis, especially for roadway segments not subject to special event traffic.

Nie et al. (2010) enhanced travel reliability of highway users by providing them with reliable route guidance produced through newly developed routing algorithms. These algorithms were validated and implemented using real traffic data. Phase-I of the project focused on demonstrating the value of reliable route guidance by developing and disseminating Chicago Testbed for Reliable Routing (CTR), while Phase II aimed at bringing the implementation of reliable routing technology to the next stage through initial deployment of CTR.

Hainen et al. (2011) proposed a Bluetooth MAC address sampling technique to assess route choice and travel time. The proposed technique was used to evaluate the impacts of a bridge closure in Indiana on four possible alternate routes. Their study indicates that the route choice behavior was consistent with the observed travel time estimates. The proposed technique is not only cost-effective to deploy but also the direct measurement of travel times and route choice is useful for public agencies to assess mobility and travel time reliability.

Rakha et al. (2011) examined existing studies that had used video cameras and other onboard devices to collect data. They determined the potential for using such data to explore how to modify driver behavior in order to reduce non-recurring congestion and, hence, the travel time unreliability.

Kwon et al. (2011) proposed an empirical, corridor-level method to divide the travel time unreliability or variability over a freeway section into various components such as incidents, weather, work zones, special events, and inadequate base capacity or bottlenecks. Results from applying the methodology to a 30.5 mile corridor in San Francisco, CA indicate that traffic crashes contributed 15.1% during the morning and 25.5% during the afternoon, among others, and most of the remaining reliability came from recurrent bottlenecks**.**

Figliozzi et al. (2011) produced informative performance measures and segments using Global Positioning Systems (GPS) data. They proposed a methodology by processing and through aggregation of GPS data to identify distinct segments and characteristics of travel time reliability in freight corridors.

Pu (2011) analytically examined a number of reliability measures and explored their mathematical relationships and interdependencies with an assumption that travel time follows a log-normal distribution using percent point function, which is a subset of reliability measure expressed in relation to the scale/shape parameter of the lognormal distribution or to both. Instead of standard deviation, it was found that coefficient of variation is a good proxy for several other reliability measures. However, when travel times are heavily skewed, Pu (2011) recommended median-based buffer index or failure rate as use of the average-based buffer index or average-based failure rate is not always appropriate.

Edwards et al. (2012) investigated travel time reliability using probe vehicle-based travel time data for 2010 acquired from private sector by Virginia DOT. They quantified travel time reliability for 15 work zones using 95th percentile travel time, mean buffer index and PTI. Results from their analysis indicate that work zone mean buffer index, PTI, and 95th percentile travel time rates were higher by 48%, 18%, and 16%, respectively. Also, lane closures occurred during off-peak periods. Work zones that involved lane closures experienced increases in their mean buffer index, PTI, and 95th percentile travel time with rates of 67%, 23%, and 22%, respectively. It was concluded that annual average daily traffic per lane and the number of access points per mile were found to have the most obvious relationships with declines in reliability at work zones.

Small et al. (2005) adopted the quantitative measure of variability as the upper tail of the distribution of travel times. This is specifically the difference between the 80^{th} and 50^{th} percentile travel times, arguing that this measure is better than a symmetric standard deviation, as travelers worry about being late than being early. Planning for the 80^{th} percentile travel time would mean arriving late for only 20% of the trips. Based on this, "travel time equivalents" can be defined using both typical (average) and reliability components as the same unit. The travel time equivalents are mathematically presented as follows.

$$TT_e = TT_m + a * (TT_{80} - TT_{50}) \quad \text{Eq. 2.11}$$

where,

TT_e = Travel time equivalent on the segment or facility,

a = Reliability Ratio (Value of Reliability (VOR) / Value of Time (VOT)),

TT_m = Mean travel time, and,

TT_{80} and TT_{50} are the 80^{th} and 50^{th} percentile travel times, respectively.

The end result is an estimation of equivalent delay value, normalized to segment length (delay per mile). The LOS ranges would then be set on delay per mile. Though this method provides a single composite value for facility performance, calculation methods and reliability ratios are required to be established. SHRP 2 Project C04 suggests a range of 0.5 to 1.5 for reliability ratio, but a review of past studies suggests that the range is more in the 0.9-1.2 range. Therefore, a value of 1.0 seems to be very reasonable for composite trips, though previous research indicates that the value of reliability varies by trip purpose.

Cambridge Systematics Inc. (2013) analyzed the effects of non-recurring congestion such as incidents, weather, work zones, special events, traffic control devices, demand, and bottlenecks. Their study explained the importance of travel time distributions for measuring reliability and recommended specific reliability performance measures. Numerous non-recurring congestion mitigation procedures were identified and models to predict such events were developed with an indication of their relative importance. The models were based on three empirical methods,

before and after studies, a "data poor" approach that resulted in a parsimonious and easy-to-apply set of models, and a "data rich model" that used cross-section inputs including data on selected factors known to directly affect non-recurring congestion. It was found that travel time reliability could be improved by reducing demand, increasing capacity, and enhancing operations.

Although the aforementioned studies provide reasonable methodologies for travel time reliability, there certainly seem to be a lack of consensus on the best reliability method for transportation planning related decisions.

2.3. Level-of-Service (LOS) Based on Reliability

LOS definitions require cutoff points (boundaries) of the measurement unit for each LOS range. One or more options for defining reliability based LOS can be proposed for use by practitioners. Such LOS criteria based on reliability measures should be scoped for consistent and accurate comparison between facilities. Kittelson and Vandehey (2013) discussed several options for defining reliability based LOS criteria. They are:

- Reliability LOS based on current LOS ranges
- Freeway reliability LOS based on travel speed ranges
- Freeway reliability LOS based on most restrictive condition
- Reliability LOS based on the value of travel

The simplest method for defining reliability LOS is to use the existing Highway Capacity Manual (HCM) recommended LOS definitions (example, density for basic freeway segments and average travel speed for urban streets). However, the definition could be based solely on the percent of trips in LOS F alone (oversaturated conditions) as travel times do not vary much over a wide range of density-based LOS ranges (A to E are in the unsaturated range) for freeways. Also, the density thresholds for weaving sections are lower than other freeway sections, which, in turn, further complicate the use of density as the fundamental measure of reliability.

The LOS based on travel speed ranges may be based on percentages of the free flow speed. The concept could be consistently adapted to freeways as well as other urban streets segments. Due to the insensitivity of travel speeds to a wide range of density and volume-to-capacity values (current LOS A through D), LOS ranges may be limited to the oversaturated conditions. However, the problem is to present a distribution rather than a single LOS value.

The LOS based on current methods and travel speed ranges provide a distribution rather than a single "grade" to define LOS. This may be confusing to the non-technical parties who are used to a single LOS value. Alternatively one could restrict reporting to the percentage of trips greater than or equal to each travel speed. Though this approach overcomes the problem of presenting a distribution, two values are required to be set for providing a percentage threshold for the trips that fail to meet the established criteria.

The LOS based on value of travel approach is to translate both the value of typical (average) travel time and travel time reliability into travel time equivalent values to assign a cost to them. Afterwards, the LOS ranges are assigned based on unit costs per traveler.

However, literature documents little to no published research on integrating or comparing LOS from travel time related reliability measures to traditional LOS measures (density, speed, delay or % time spent following). Also, traditional LOS measures vary by facility type. Proposing and developing a measure that can be consistently adopted for all facilities would help

better assess transportation system needs and prioritize resources. Connecting it to the context, this could be termed or referred to as the level of reliability.

2.3. Future of Travel Time Reliability in Transportation Sector

The FHWA projects a 65% growth in domestic freight volumes between 1998 and 2020. This rapid growth in truck volume can be attributed to a number of factors such as the shift of significant freight activity from rail and other modes to truck, and the changes in the economy and business practices such as just-in-time deliveries of inventory items that increase delivery frequencies (Polzin, 2006). Therefore, it is expected that there will be a three percent annual growth in truck vehicle miles traveled (FHWA, 2013).

In addition, e-commerce is advancing significantly and will influence the land use patterns and vehicle miles traveled over the next few decades. The home-based shopping via catalogs, cable television shows, and the internet, and highly efficient package delivery companies, both private and public entities, will increase trips from local businesses to homes. There is also an expected shift in the shipment procedure which would put more emphasis toward less-than-truck load or smaller truck freight shipments than long-haul carriers as a significant portion of all types of retailing required next-day delivery, same-day delivery, and just-in-time delivery.

Furthermore, the demographic shifts likely to occur between 2000 and 2020 in the United States will also generate more traffic on urban roadways that will, in turn, increase the congestion level. The United States Census Bureau projects that the population will be somewhat better off economically, with smaller households and increased household vehicle ownership (Bonnaire, 2012). In the coming years, the older driver population on the road is expected to at least double, which is attributable to both the overall increase in the older population, and the anticipated trend for older women to drive in greater proportions than their previous cohorts (Pisarski, 2006). Therefore, the shift in these household composition, labor force participation and household income changes, and shifts in licensing and vehicle ownership will affect transportation and individual mobility, which is expected to increase the highway vehicle miles traveled by 60% in 2020 (Bonnaire, 2012).

Concurrently, researchers and practitioners are well aware of the impacts of travel time reliability and, therefore, consequently have adjusted their methodologies. For instance, in transportation planning, it is found that value of travel time reliability significantly enhances the mode choice models (Pinjari and Bhat, 2006; Liu et al., 2007). The second SHRP2 identifies travel time reliability as one of the four transportation factors that needs to be addressed during a highway capacity expansion decision making process (Cambridge Systematics Inc., 2009).

Travel time reliability research is developing the means for state DOTs and MPOs to fully integrate mobility and reliability performance measures and strategies into the transportation planning processes. Studies are under way to include reliability factors into the HCM. In addition to that, a guide on roadway design features to support the reduction of delays that in turn reduce travel time reliability is needed. Such features can be considered for inclusion in the American Association of State Highway and Transportation Officials (AASHTO) Policy on Geometric Design of Highways and Streets (TRB, 2011).

However, reliability requirements for personal trips vary considerably. The factors include the type of trips (commuter, personal, and social/recreational), ToD (peak versus off-peak period), and the travel setting and conditions. In addition, reliability requirements vary based on the roadway network used, geographic areas (urban or rural), and the factors that contribute to the uncertainty of arrival time, such as traffic crashes or work zones.

CHAPTER 3: EVALUATION OF RELIABILITY PERFORMANCE MEASURES

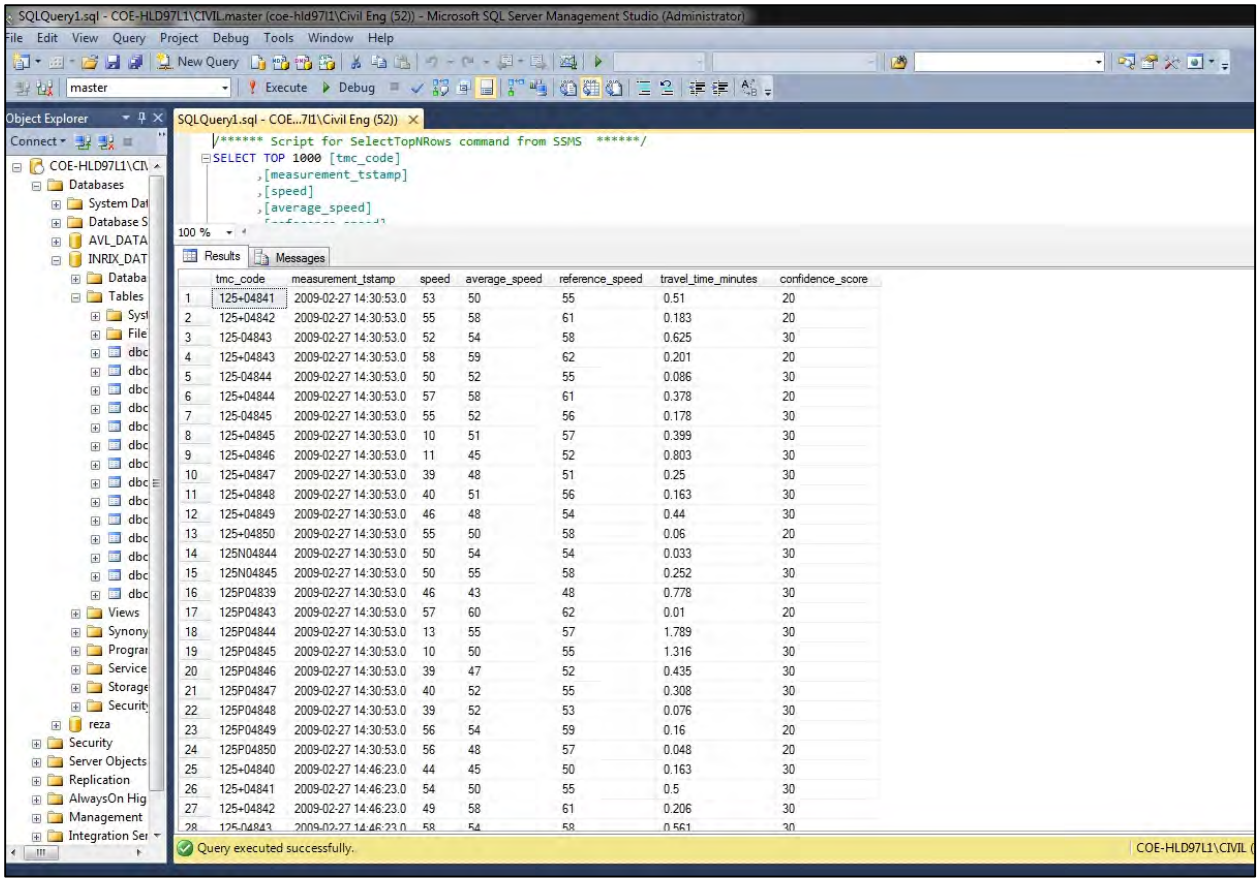
Travel time is one of the most important measures for evaluating the operational efficiency of links and corridors in the transportation networks. Travel time reliability has been widely recognized as an important element of a traveler's route and departure time choice. Further, incorporating travel time variability into traffic network analysis models and finding reliable alternate paths motivates better understanding of travel time data and substantial algorithmic development efforts. In spite of several research efforts, practitioners are still unclear as to how the travel time reliability performance measures are related to each other and which one to use for planning related decisions.

3.1. Data Collection

As stated previously, one of the objectives of this project report is to present an evaluation of the relationship between various travel time related reliability measures. Raw data for the city of Charlotte, North Carolina for each Traffic Message Channel (TMC) or link in the transportation network was obtained from INRIX (2014). The raw data file has Traffic Message Channel (TMC) code (tmc_code), time-stamp (measurement_tstamp), speed (speed), average speed (average_speed), reference speed (reference_speed), travel time (travel_time_minutes) and score (confidence_score). Each field in the raw data file is briefly described below (INRIX, 2013).

1. Traffic Message Channel (TMC) - defines section identity of the roadway segment.
2. Speed - current estimated space mean speed for the roadway segment in miles per hour.
3. Average speed - historical average mean speed for the roadway segment for that Tod (hour) and DoW in miles per hour.
4. Reference speed - calculated "free flow" mean speed for roadway segment in miles per hour. It is the 85^{th} percentile point of the observed speeds on that segment.
5. Travel time - current estimated travel time it takes to traverse the roadway segment in minutes.
6. Score - an indicator of data type (30 indicates real-time data; 20 indicates real-time data across multiple segments; 10 indicates historical data).

Figure 2 shows the snapshot of raw data obtained from INRIX. The data obtained have travel time data aggregated for every one minute interval with other trip characteristics such as date of the trip, time of trip, and identified TMC code.



	tmc_code	measurement_tstamp	speed	average_speed	reference_speed	travel_time_minutes	confidence_score
1	125+04841	2009-02-27 14:30:53.0	53	50	55	0.51	20
2	125+04842	2009-02-27 14:30:53.0	55	58	61	0.183	20
3	125-04843	2009-02-27 14:30:53.0	52	54	58	0.625	30
4	125+04843	2009-02-27 14:30:53.0	58	59	62	0.201	20
5	125-04844	2009-02-27 14:30:53.0	50	52	55	0.086	30
6	125+04844	2009-02-27 14:30:53.0	57	58	61	0.378	20
7	125-04845	2009-02-27 14:30:53.0	55	52	56	0.178	30
8	125+04845	2009-02-27 14:30:53.0	10	51	57	0.399	30
9	125+04846	2009-02-27 14:30:53.0	11	45	52	0.803	30
10	125+04847	2009-02-27 14:30:53.0	39	48	51	0.25	30
11	125+04848	2009-02-27 14:30:53.0	40	51	56	0.163	30
12	125+04849	2009-02-27 14:30:53.0	46	48	54	0.44	30
13	125+04850	2009-02-27 14:30:53.0	55	50	58	0.06	20
14	125N04844	2009-02-27 14:30:53.0	50	54	54	0.033	30
15	125N04845	2009-02-27 14:30:53.0	50	55	58	0.252	30
16	125P04839	2009-02-27 14:30:53.0	46	43	48	0.778	30
17	125P04843	2009-02-27 14:30:53.0	57	60	62	0.01	20
18	125P04844	2009-02-27 14:30:53.0	13	55	57	1.789	30
19	125P04845	2009-02-27 14:30:53.0	10	50	55	1.316	30
20	125P04846	2009-02-27 14:30:53.0	39	47	52	0.435	30
21	125P04847	2009-02-27 14:30:53.0	40	52	55	0.308	30
22	125P04848	2009-02-27 14:30:53.0	39	52	53	0.076	30
23	125P04849	2009-02-27 14:30:53.0	56	54	59	0.16	20
24	125P04850	2009-02-27 14:30:53.0	56	48	57	0.048	20
25	125+04840	2009-02-27 14:46:23.0	44	45	50	0.163	30
26	125+04841	2009-02-27 14:46:23.0	54	50	55	0.5	30
27	125+04842	2009-02-27 14:46:23.0	49	58	61	0.206	30

Figure 2: Snapshot of Raw Data Downloaded from INRIX

3.2. Selection of Performance Measures

Table 1 summarizes different travel time reliability measures that were defined and used by practitioners and researchers in the past. Out of them, six reliability indices or variance related measures were considered in this study. They are described briefly next.

1) Buffer time (BT): It is the difference of 95th percentile travel time and the average travel time. It represents the required additional time for an on time performance (Lomax et al., 2004).

$$\text{Buffer time (BT)} = TT_{95} - TT_{Ave} \quad \text{Eq. 3.1}$$

2) Buffer time index (BTI): It is the ratio of difference of 95th percentile travel time and the average travel time to the average travel time (Lomax et al., 2004).

$$\text{Buffer time index (BTI)} = \frac{TT_{95} - TT_{Avg}}{TT_{Avg}} \times 100 \quad \text{Eq. 3.2}$$

3) Planning time index (PTI): It is the ratio of 95th percentile travel time and the free flow travel time or 15th percentile time (Sisiopiku and Islam, 2012).

Planning time index (PTI) = $\frac{TT_{95}}{TT_{free\ flow}}$ Eq. 3.3

4) Travel time index (TTI): It is the ratio of average travel time to the free flow travel time (Lyman and Bertini, 2008).

Travel time index (TTI) = $\frac{TT_{Ave}}{TT_{free\ flow}}$ Eq. 3.4

5) λ skew: It is the ratio of difference in 90th percentile and 50th percentile travel times to the differences in 50th percentile and 10th percentile travel times (van Lint et al., 2004).

λ skew = $(TT_{90} - TT_{50})/(TT_{50} - TT_{10})$ Eq. 3.5

6) λ variance*:* It is the ratio of difference between 90th percentile and 10th percentile to the 50th percentile travel time (Bogers et al., 2008).

λ variance = $(TT_{90} - TT_{10})/TT_{50}$ Eq. 3.6

The following travel time and travel time variation related measures were also considered in addition to the aforementioned reliability indices or variance related measures.

- Minimum travel time
- Average travel time
- Maximum travel time
- 10th, 15th, 50th, 85th, 90th, and 95th percentile travel times
- Travel time variation based on 85th, 90th, and 95th percentile travel times

3.3. Data Processing & Computation of Reliability Measures

The data processing was performed using Microsoft SQL server. Data tools and query applications were developed to compute various travel time measures. They include maximum travel time, minimum travel time, average travel time, 50th percentile travel time, 85th percentile travel times, and 95th percentile travel time. The factors considered in computing these travel times are ToD and DoW. Based on the computed travel times, the selected reliability measures were computed for the selected time periods of the analysis. Figure 3 shows the snapshot of the processed data using Microsoft SQL Server.

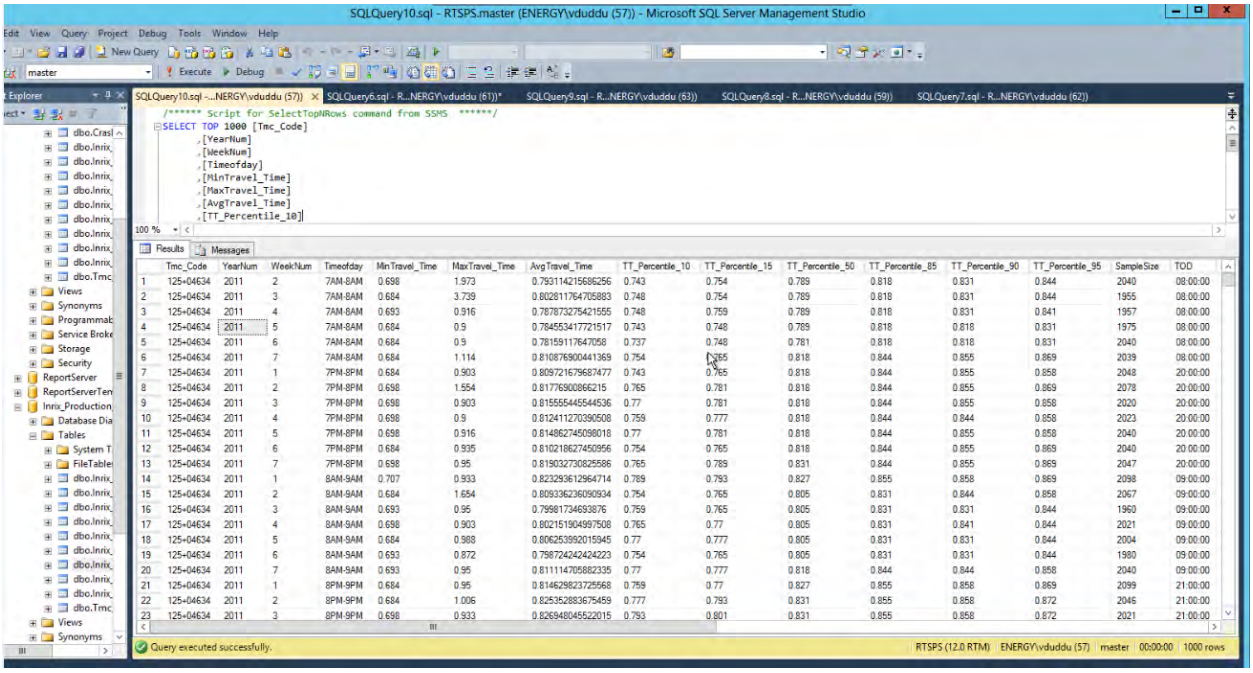


Figure 3: Snapshot of Processed Data using Microsoft SQL Server

3.4. Analysis

The statistical analysis was carried out for the following days of week.

1) Monday
2) Wednesday
3) Friday
4) Saturday
5) Weekday (Monday to Friday)
6) Weekend (Saturday and Sunday)
7) All days

For each DoW considered, data was extracted and analysis performed for morning peak hour (8 AM - 9 AM), afternoon peak hour (12 PM -1 PM), evening peak hour (5 PM - 6 PM), evening off-peak hour (9 PM - 10 PM) and all-day. A total of 7 sets of data were prepared for the analysis. Each set of data comprised of the aforementioned travel time reliability measures. The sample size of each set of data varied with the ToD.

The correlation matrices were then developed to examine the relationship between the selected travel time and reliability measures for each year (2009 to 2012). For illustration purposes, correlation matrices developed based on the data for the year 2010 are discussed in this chapter. However, the correlation matrices for selected time period and days of the weeks, for years 2009, 2010, 2011 and 2012, are shown in Appendix.

The following criteria were used to assess the relationship based on computed Pearson correlation coefficient.

Low Correlation: for values ~ (0 - 0.3)
Medium Correlation ~ (0.3 - 0.7)
High Correlation ~ (0.7 - 1.0)

3.5. Results and Discussion

The results obtained from statistical analysis are presented next.

3.5.1. Comparison by Day-of-the-week (DoW)

Tables 2 to 5 show correlation matrices for the selected travel time and reliability measures for Wednesday, Saturday, weekday and weekend, respectively. The values shown in red text with a red fill in the correlation matrices indicate very low correlation between the pair of measures (Pearson correlation coefficient value less than 0.1). The values with green text with green fill indicate low correlation between the pair of measures (Pearson correlation coefficient value greater than 0.1 and less than 0.3), while the values with black text and no fill indicate a high correlation (Pearson correlation coefficient value greater than 0.3). The sample size shown in the results table is less than the original sample size due to a divisional error during the calculation of λ skew.

It was observed that the Pearson correlation coefficient values in the correlation matrices for the travel time measures (from minimum travel time to the 95th percentile travel time) with respect to the reliability measures (BTI, PTI, λ skew, λ variance, and TTI) is less than 0.3, indicating a weak correlation. The Pearson correlation coefficient between BT and the minimum and maximum travel time is greater than 0.3 in all the cases except for the Wednesday - all-day. λ skew values, in all the cases except for Wednesday, are not correlated with the other reliability measures.

Table 2 shows the Pearson correlation coefficient matrix for travel time measures and the reliability indices for all-day Wednesday. The table provides information about different parameters such as travel times i.e., minimum, maximum and average travel times and also different percentile travel times from 10th percentile to 95th percentile travel times. It also has the travel time variations and different reliability indices. From the Pearson correlation coefficient matrix, one can observe that all the reliability indices except the BT are not correlated with the travel times. All the travel times and travel time variations along with the BT are correlated to each other. The BT by definition says that it is the difference between the 95th percentile and the average travel times, which means if one of the parameter increases the other one increases (and vice versa). Since BT indicates the variation in travel times, it can be used for before and after evaluations.

Table 3 shows the same trends as of Table 2 except for the BT which it is not correlated with the maximum travel time. The results shown in Table 4, for weekday, follow the same trend. Even in this case BT is not correlated with the minimum travel time.

Table 2: Selected Performance Measures Correlation Matrix - Wednesday (All-Day)

Sample Size = 307 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	1.00	0.61	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	1.00	0.61	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.99	0.61	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.99	0.61	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.61	0.99	0.97	0.97	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.89	0.63	0.93	0.90	0.89	0.90	0.92	0.95	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.41	0.32	0.50	0.41	0.41	0.47	0.52	0.62	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.41	0.32	0.50	0.41	0.41	0.47	0.52	0.62	0.68	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.37	0.40	0.46	0.38	0.38	0.40	0.44	0.54	0.75	0.81	0.81	1.00	-	-	-	-	-	-
BT	0.32	0.37	0.40	0.33	0.33	0.33	0.37	0.48	0.71	0.75	0.75	0.99	1.00	-	-	-	-	-
BTI	-0.04	0.16	0.03	-0.03	-0.04	-0.03	0.01	0.10	0.32	0.49	0.49	0.71	0.73	1.00	-	-	-	-
PTI	-0.06	0.12	0.04	-0.06	-0.06	0.00	0.05	0.12	0.28	0.65	0.65	0.68	0.64	0.86	1.00	-	-	-
λ Skew	-0.09	0.03	-0.04	-0.08	-0.08	-0.09	-0.04	0.07	0.19	0.55	0.55	0.52	0.56	0.65	0.52	1.00	-	-
λ Var	-0.14	-0.02	-0.06	-0.13	-0.14	-0.09	-0.03	0.07	0.16	0.70	0.70	0.54	0.51	0.66	0.77	0.81	1.00	-
TTI	-0.08	0.04	0.02	-0.08	-0.08	0.03	0.05	0.08	0.12	0.57	0.57	0.37	0.27	0.37	0.79	0.15	0.60	1.00

Table 3: Selected Performance Measures Correlation Matrix - Saturday (All-day)

Sample Size-300 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.86	0.49	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.86	0.48	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.86	0.48	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.85	0.48	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.85	0.48	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.85	0.48	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.85	0.48	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.37	0.23	0.54	0.47	0.47	0.56	0.59	0.60	0.60	1.00	-	-	-	-	-	-	-	-
TTV_85	0.24	0.15	0.41	0.33	0.33	0.43	0.46	0.46	0.47	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.37	0.26	0.53	0.46	0.46	0.54	0.57	0.58	0.60	0.95	0.90	1.00	-	-	-	-	-	-
BT	0.38	0.22	0.53	0.48	0.48	0.54	0.56	0.58	0.61	0.84	0.76	0.96	1.00	-	-	-	-	-
BTI	-0.24	-0.04	-0.17	-0.22	-0.22	-0.16	-0.14	-0.13	-0.09	0.44	0.45	0.57	0.62	1.00	-	-	-	-
PTI	-0.17	-0.01	-0.04	-0.12	-0.12	-0.01	0.01	0.02	0.03	0.75	0.81	0.73	0.60	0.74	1.00	-	-	-
λ Skew	-0.15	-0.07	-0.21	-0.21	-0.21	-0.22	-0.21	-0.20	-0.19	-0.06	-0.05	0.02	0.09	0.44	0.11	1.00	-	-
λ Var	-0.23	-0.06	-0.14	-0.21	-0.21	-0.12	-0.09	-0.09	-0.08	0.62	0.68	0.60	0.51	0.83	0.89	0.30	1.00	-
TTI	-0.13	0.00	0.00	-0.08	-0.08	0.03	0.05	0.05	0.06	0.77	0.84	0.70	0.53	0.58	0.98	0.00	0.83	1.00

Table 4: Selected Performance Measures Correlation Matrix - Weekday (All-day)

Sample Size = 307 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.46	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.65	0.72	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.65	0.71	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.65	0.71	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.65	0.71	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.65	0.70	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.64	0.71	0.99	0.98	0.98	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.61	0.68	0.93	0.90	0.90	0.90	0.91	0.95	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.31	0.35	0.53	0.45	0.45	0.51	0.55	0.63	0.70	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.29	0.51	0.43	0.43	0.52	0.56	0.58	0.55	0.84	1.00	-	-	-	-	-	-	-
TTV_95	0.31	0.38	0.49	0.41	0.41	0.43	0.46	0.55	0.77	0.79	0.51	1.00	-	-	-	-	-	-
BT	0.28	0.35	0.44	0.36	0.36	0.36	0.39	0.49	0.73	0.74	0.40	0.99	1.00	-	-	-	-	-
BTI	0.03	0.09	0.05	-0.02	-0.02	-0.01	0.02	0.10	0.33	0.50	0.23	0.70	0.73	1.00	-	-	-	-
PTI	-0.02	0.05	0.05	-0.05	-0.05	0.02	0.05	0.12	0.29	0.68	0.58	0.67	0.63	0.86	1.00	-	-	-
λ Skew	-0.03	-0.05	-0.08	-0.11	-0.11	-0.12	-0.08	0.00	0.12	0.42	0.11	0.41	0.45	0.64	0.50	1.00	-	-
λ Var	-0.07	-0.09	-0.07	-0.15	-0.15	-0.10	-0.05	0.04	0.14	0.67	0.52	0.49	0.47	0.67	0.79	0.76	1.00	-
TTI	-0.08	-0.01	0.02	-0.08	-0.08	0.03	0.06	0.08	0.13	0.61	0.77	0.37	0.27	0.38	0.80	0.14	0.63	1.00

Table 5: Selected Performance Measures Correlation Matrix - Weekend (All-day)

Sample Size = 301 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.45	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.85	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.85	0.54	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.85	0.54	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.84	0.53	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.84	0.53	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.84	0.53	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.84	0.54	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.34	0.23	0.51	0.44	0.43	0.53	0.56	0.56	0.57	1.00	-	-	-	-	-	-	-	-
TTV_85	0.22	0.14	0.38	0.30	0.30	0.40	0.43	0.44	0.44	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.25	0.49	0.42	0.42	0.50	0.53	0.54	0.56	0.93	0.90	1.00	-	-	-	-	-	-
BT	0.36	0.25	0.51	0.45	0.45	0.51	0.54	0.55	0.58	0.83	0.77	0.96	1.00	-	-	-	-	-
BTI	-0.23	-0.07	-0.16	-0.22	-0.22	-0.15	-0.13	-0.12	-0.08	0.48	0.51	0.62	0.65	1.00	-	-	-	-
PTI	-0.16	-0.03	-0.03	-0.12	-0.12	-0.01	0.01	0.02	0.03	0.77	0.83	0.76	0.62	0.75	1.00	-	-	-
λ Skew	-0.13	-0.09	-0.19	-0.19	-0.19	-0.21	-0.19	-0.19	-0.18	-0.05	-0.03	0.00	0.07	0.41	0.09	1.00	-	-
λ Var	-0.23	-0.09	-0.14	-0.21	-0.21	-0.12	-0.09	-0.09	-0.08	0.65	0.72	0.62	0.51	0.83	0.89	0.27	1.00	-
TTI	-0.13	-0.01	0.00	-0.09	-0.09	0.03	0.05	0.05	0.06	0.79	0.85	0.73	0.55	0.62	0.98	-0.01	0.84	1.00

3.5.2. Correlation by Time-of-the-day (ToD)

Tables 6 to 13 shows the results from Pearson correlation coefficient analysis for the selected time periods using weekday and weekend datasets. From the results obtained, the Pearson correlation coefficients of travel time measures with respect to the reliability measures are less than 0.3 i.e., not correlated with each other.

Table 6 shows the Pearson correlation coefficient matrix for a weekday morning peak hour. The minimum travel time, 10th percentile travel time and 15th percentile are not correlated with the travel time variations and reliability indices. If one observes the results shown in tables 7, 8 and 9 (i.e., for the afternoon, evening and the night peak hour), they show almost the same trend during these periods with a very little variation in the BT and the BTI values.

Table 6: Selected Performance Measures Correlation Matrix - Weekday (8 AM - 9 AM)

Sample Size-307 (Original Sample Size 311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.56	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.76	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	1.00	0.58	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	1.00	0.59	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.94	0.70	0.99	0.95	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.77	0.79	0.96	0.78	0.79	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.72	0.80	0.94	0.74	0.74	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.66	0.82	0.90	0.67	0.67	0.82	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.26	0.69	0.63	0.28	0.29	0.52	0.81	0.86	0.89	1.00	-	-	-	-	-	-	-	-
TTV_85	0.25	0.68	0.62	0.27	0.28	0.52	0.81	0.85	0.88	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.27	0.72	0.63	0.28	0.29	0.51	0.81	0.85	0.90	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.25	0.70	0.60	0.27	0.27	0.48	0.78	0.84	0.89	0.98	0.96	1.00	1.00	-	-	-	-	-
BTI	-0.04	0.46	0.23	-0.03	-0.02	0.11	0.37	0.43	0.52	0.63	0.59	0.69	0.72	1.00	-	-	-	-
PTI	-0.02	0.50	0.30	-0.01	0.00	0.21	0.47	0.52	0.59	0.74	0.73	0.76	0.76	0.89	1.00	-	-	-
λ Skew	-0.02	0.26	0.09	-0.01	-0.01	-0.02	0.16	0.22	0.30	0.32	0.26	0.39	0.45	0.80	0.55	1.00	-	-
λ Var	-0.03	0.46	0.26	-0.01	-0.01	0.15	0.43	0.49	0.56	0.70	0.67	0.73	0.75	0.95	0.92	0.75	1.00	-
TTI	-0.03	0.43	0.28	-0.02	-0.01	0.23	0.44	0.47	0.51	0.68	0.69	0.67	0.64	0.69	0.93	0.29	0.76	1.00

Table 7*:* Selected Performance Measures Correlation Matrix - Weekday (12 PM - 1 PM)

Sample Size-306 (Original Sample Size 311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.64	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.92	0.63	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.92	0.63	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.91	0.62	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.91	0.62	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.91	0.62	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.91	0.62	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.30	0.57	0.49	0.49	0.60	0.62	0.62	0.62	1.00	-	-	-	-	-	-	-	-
TTV_85	0.39	0.25	0.50	0.41	0.41	0.53	0.54	0.54	0.54	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.49	0.34	0.60	0.52	0.52	0.62	0.64	0.64	0.64	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.56	0.26	0.66	0.61	0.61	0.69	0.71	0.71	0.71	0.94	0.91	0.95	1.00	-	-	-	-	-
BTI	-0.31	-0.35	-0.30	-0.35	-0.35	-0.28	-0.26	-0.26	-0.26	0.35	0.38	0.34	0.33	1.00	-	-	-	-
PTI	-0.13	-0.10	-0.07	-0.16	-0.16	-0.04	-0.02	-0.02	-0.01	0.73	0.78	0.72	0.60	0.74	1.00	-	-	-
λ Skew	-0.14	-0.07	-0.14	-0.13	-0.13	-0.15	-0.14	-0.13	-0.14	-0.09	-0.08	-0.10	-0.05	0.39	0.04	1.00	-	-
λ Var	-0.23	-0.21	-0.21	-0.28	-0.28	-0.19	-0.17	-0.17	-0.17	0.51	0.55	0.48	0.40	0.92	0.84	0.37	1.00	-
TTI	-0.08	-0.03	-0.02	-0.11	-0.11	0.02	0.03	0.03	0.04	0.77	0.82	0.75	0.61	0.63	0.99	-0.04	0.77	1.00

Table 8: Selected Performance Measures Correlation Matrix - Weekday (5 PM - 6 PM)

Sample Size-306 (Original Sample Size 311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.52	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.84	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.99	0.58	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.97	0.60	0.91	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.88	0.69	0.98	0.93	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.70	0.74	0.97	0.76	0.79	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.66	0.73	0.94	0.71	0.73	0.87	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.59	0.73	0.91	0.65	0.67	0.81	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.32	0.64	0.75	0.39	0.42	0.63	0.89	0.92	0.95	1.00	-	-	-	-	-	-	-	-
TTV_85	0.32	0.64	0.75	0.39	0.42	0.64	0.89	0.92	0.94	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.65	0.74	0.39	0.41	0.61	0.88	0.92	0.95	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.32	0.63	0.72	0.38	0.40	0.58	0.86	0.91	0.95	0.99	0.97	1.00	1.00	-	-	-	-	-
BTI	-0.11	0.37	0.18	-0.07	-0.06	0.05	0.30	0.36	0.42	0.51	0.48	0.54	0.56	1.00	-	-	-	-
PTI	-0.07	0.42	0.26	-0.04	-0.03	0.13	0.41	0.46	0.51	0.63	0.61	0.64	0.64	0.93	1.00	-	-	-
λ Skew	-0.05	0.19	0.07	-0.04	-0.04	-0.04	0.14	0.20	0.25	0.29	0.23	0.32	0.36	0.77	0.65	1.00	-	-
λ Var	-0.08	0.38	0.22	-0.05	-0.04	0.08	0.36	0.42	0.46	0.57	0.55	0.58	0.59	0.91	0.95	0.76	1.00	-
TTI	-0.09	0.39	0.25	-0.05	-0.04	0.16	0.38	0.42	0.45	0.58	0.59	0.57	0.55	0.74	0.92	0.40	0.81	1.00

Table 9: Selected Performance Measures Correlation Matrix - Weekday (9 PM - 10 PM)

Sample Size-308 (Original Sample Size 311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.31	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.95	0.32	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.96	0.31	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.96	0.31	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.95	0.31	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.95	0.31	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.95	0.31	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.94	0.31	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.18	0.55	0.48	0.48	0.57	0.60	0.61	0.61	1.00	-	-	-	-	-	-	-	-
TTV_85	0.34	0.15	0.44	0.36	0.36	0.45	0.49	0.49	0.50	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.48	0.20	0.58	0.51	0.51	0.59	0.63	0.63	0.64	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.53	0.14	0.63	0.57	0.57	0.63	0.66	0.67	0.69	0.89	0.82	0.96	1.00	-	-	-	-	-
BTI	-0.23	-0.14	-0.18	-0.23	-0.23	-0.17	-0.14	-0.13	-0.11	0.40	0.44	0.46	0.48	1.00	-	-	-	-
PTI	-0.14	-0.04	-0.06	-0.14	-0.14	-0.04	-0.01	-0.01	0.00	0.72	0.79	0.68	0.53	0.73	1.00	-	-	-
λ Skew	-0.13	-0.03	-0.13	-0.13	-0.13	-0.14	-0.12	-0.12	-0.11	-0.01	-0.03	0.03	0.10	0.40	0.11	1.00	-	-
λ Var	-0.24	-0.07	-0.17	-0.24	-0.24	-0.16	-0.12	-0.12	-0.12	0.57	0.63	0.53	0.42	0.81	0.88	0.31	1.00	-
TTI	-0.11	0.00	-0.02	-0.11	-0.11	0.00	0.03	0.03	0.03	0.74	0.81	0.67	0.48	0.55	0.97	0.00	0.80	1.00

The results shown in tables 10 to 13 show the Pearson correlation coefficient analysis for weekend travel times for the four study hours. The reliability indices are not related to the travel times, except for the BT. But in the case of evening peak hour 5PM to 6 PM, all the reliability indices including the BT and travel time variation are not correlated to travel time measures. This indicates that for the evening peak hour the travel times are higher compared to other times during the weekends. The TTI seem to be more appropriate to quantify congestion, while BTI and PTI help evaluate the condition of the facility and track reliability over time.

Table 10: Selected Performance Measures Correlation Matrix - Weekend (8 AM - 9 AM)

Sample Size = 305 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.86	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.87	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.86	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.97	0.87	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.48	0.53	0.56	0.48	0.48	0.58	0.61	0.61	0.61	1.00	-	-	-	-	-	-	-	-
TTV_85	0.37	0.45	0.46	0.37	0.37	0.47	0.50	0.51	0.51	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.51	0.57	0.58	0.51	0.50	0.60	0.62	0.63	0.63	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.59	0.62	0.66	0.60	0.60	0.67	0.70	0.70	0.71	0.94	0.89	0.97	1.00	-	-	-	-	-
BTI	-0.28	-0.11	-0.19	-0.25	-0.25	-0.18	-0.16	-0.15	-0.15	0.44	0.49	0.45	0.44	1.00	-	-	-	-
PTI	-0.11	0.04	-0.03	-0.12	-0.12	-0.01	0.02	0.02	0.03	0.76	0.83	0.74	0.62	0.75	1.00	-	-	-
λ Skew	-0.12	-0.08	-0.12	-0.12	-0.12	-0.13	-0.11	-0.11	-0.11	-0.01	0.00	0.00	0.05	0.38	0.07	1.00	-	-
λ Var	-0.19	-0.04	-0.12	-0.20	-0.20	-0.11	-0.07	-0.07	-0.07	0.63	0.69	0.61	0.51	0.88	0.89	0.27	1.00	-
TTI	-0.07	0.07	0.01	-0.08	-0.09	0.03	0.06	0.06	0.06	0.78	0.85	0.75	0.61	0.65	0.99	0.00	0.85	1.00

Table 11: Selected Performance Measures Correlation Matrix - Weekend (12 PM - 1 PM)

Sample Size = 306 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.68	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.69	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.69	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.69	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.69	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.69	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.97	0.71	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.51	0.39	0.59	0.51	0.51	0.61	0.63	0.64	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.41	0.30	0.48	0.40	0.40	0.50	0.54	0.53	0.53	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.53	0.52	0.61	0.53	0.53	0.61	0.64	0.64	0.66	0.94	0.92	1.00	-	-	-	-	-	-
BT	0.57	0.56	0.64	0.58	0.58	0.64	0.66	0.67	0.69	0.85	0.80	0.97	1.00	-	-	-	-	-
BTI	-0.24	-0.04	-0.16	-0.22	-0.22	-0.15	-0.12	-0.12	-0.10	0.43	0.47	0.50	0.49	1.00	-	-	-	-
PTI	-0.11	-0.01	-0.03	-0.11	-0.11	0.00	0.02	0.02	0.03	0.73	0.79	0.68	0.54	0.75	1.00	-	-	-
λ Skew	-0.11	-0.05	-0.12	-0.12	-0.12	-0.13	-0.11	-0.11	-0.11	-0.02	-0.02	0.00	0.04	0.37	0.09	1.00	-	-
λ Var	-0.19	-0.11	-0.13	-0.20	-0.20	-0.11	-0.08	-0.08	-0.08	0.59	0.65	0.52	0.41	0.84	0.87	0.32	1.00	-
TTI	-0.07	0.00	0.00	-0.09	-0.09	0.03	0.05	0.05	0.05	0.75	0.81	0.67	0.51	0.63	0.99	0.01	0.82	1.00

Table 12*:* Selected Performance Measures Correlation Matrix - Weekend (5 PM - 6 PM)

Sample Size = 307 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.59	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.56	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.56	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.55	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.58	1.00	0.98	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.95	0.59	0.99	0.96	0.96	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.83	0.63	0.90	0.85	0.85	0.86	0.89	0.93	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.34	0.39	0.44	0.34	0.34	0.39	0.50	0.58	0.70	1.00	-	-	-	-	-	-	-	-
TTV_85	0.34	0.33	0.44	0.34	0.34	0.42	0.51	0.56	0.60	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.22	0.42	0.32	0.22	0.22	0.25	0.33	0.43	0.71	0.83	0.65	1.00	-	-	-	-	-	-
BT	0.18	0.38	0.27	0.18	0.18	0.19	0.28	0.37	0.67	0.77	0.57	0.99	1.00	-	-	-	-	-
BTI	-0.02	0.25	0.07	-0.02	-0.02	0.00	0.07	0.17	0.49	0.65	0.44	0.92	0.94	1.00	-	-	-	-
PTI	-0.04	0.22	0.06	-0.04	-0.04	0.01	0.08	0.18	0.46	0.73	0.59	0.90	0.89	0.95	1.00	-	-	-
λ Skew	-0.06	0.15	-0.01	-0.07	-0.07	-0.07	0.01	0.09	0.26	0.51	0.34	0.57	0.59	0.64	0.59	1.00	-	-
λ Var	-0.07	0.17	0.02	-0.08	-0.08	-0.04	0.07	0.17	0.37	0.82	0.68	0.78	0.77	0.81	0.86	0.71	1.00	-
TTI	-0.07	0.11	0.02	-0.09	-0.09	0.02	0.07	0.12	0.23	0.66	0.75	0.54	0.47	0.50	0.73	0.28	0.66	1.00

Table 13: Selected Performance Measures Correlation Matrix - Weekend (9 PM - 10 PM)

Sample Size = 298 (Original Sample Size-311)																		
MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.37	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.42	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.38	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.38	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.37	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.37	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.37	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.97	0.37	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.35	0.10	0.42	0.34	0.34	0.44	0.48	0.48	0.48	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.06	0.30	0.22	0.21	0.32	0.36	0.36	0.36	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.38	0.13	0.45	0.37	0.37	0.47	0.51	0.51	0.51	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.31	-0.37	0.34	0.31	0.31	0.39	0.42	0.42	0.43	0.83	0.78	0.84	1.00	-	-	-	-	-
BTI	-0.29	-0.22	-0.24	-0.29	-0.29	-0.22	-0.19	-0.18	-0.18	0.52	0.54	0.52	0.55	1.00	-	-	-	-
PTI	-0.14	-0.03	-0.06	-0.14	-0.14	-0.03	-0.01	0.00	0.00	0.79	0.83	0.78	0.59	0.74	1.00	-	-	-
λ Skew	-0.07	0.03	-0.07	-0.07	-0.07	-0.08	-0.06	-0.06	-0.06	0.05	0.06	0.05	0.10	0.39	0.08	1.00	-	-
λ Var	-0.22	-0.06	-0.17	-0.24	-0.24	-0.15	-0.11	-0.11	-0.11	0.67	0.69	0.64	0.54	0.90	0.85	0.32	1.00	-
TTI	-0.09	0.04	-0.02	-0.10	-0.11	0.01	0.03	0.04	0.04	0.80	0.85	0.78	0.54	0.61	0.98	-0.01	0.78	1.00

3.5.3. Summary of Relationship between Travel Time and Reliability Measures

Tables 14 to 20 summarize results for the selected travel times and reliability measures. Among all the travel times, the minimum travel time, maximum travel time, and average travel time are mainly considered for the analysis. From the reliability measures, the BT, BTI, PTI and the TTI are considered for the analysis. In each of the tables, the relationship between the selected measures with all other measures is observed for the selected ToD and DoW. The letter "H" indicates that it is highly correlated, the letter "M" indicates that it is moderately correlated, and the blank field indicates that the two measures are not correlated.

The summary results from Table 14 indicate that the reliability measures are moderately correlated with the minimum travel time except the BT (which is highly correlated with

minimum travel time for almost all the selected time periods), while the summary results from Table 15 show that the maximum travel time is highly correlated with all the travel times. The travel time variations and the BT are also highly correlated with maximum travel time with exceptions in some cases (Table 15). The reliability measures are moderately correlated with the maximum travel time. But in the case of weekday (8 AM - 9 AM) and weekday (5 PM - 6 PM) reliability measures are highly correlated. The travel time variation values that are not correlated are due to the low traffic volume on the selected link.

The average travel time has a good correlation with all the travel times, travel time variations and BT (Table 16). However, it is not correlated with the BTI, PTI, λ skew, λ variance and TTI.

Table17 summarizes the correlation between BT with the other travel times and reliability measures. The results show a good correlation with all the travel times and the reliability measures. It only shows some variation in its correlation with the λ skew. This measure can be used to compare two links based on variability in travel times.

Table 18 indicates that the travel times are not correlated with the BTI. However, in the case of travel time variability indices and reliability measures, there is good correlation with the BTI.

The PTI also shows similar trends as the BTI. It is not correlated to the travel times but correlated with the travel time variability and reliability measures. A variation in correlation between PTI and λ skew is observed.

Table 20 shows similar trends as the BTI and the PTI. The TTI does not have a correlation with travel time. Among the reliability measures, except the λ skew, all the values are correlated with TTI.

Table 14: Summary of Results Showing Correlation of Travel Times and Reliability Indices with the Minimum Travel Time

For Minimum Travel Time																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	H				M	
Saturady_AllDay	H	H	H	H	H	H	H	H	M	M	M	M						
Weekday_AllDay	H	H	H	H	H	H	H	H	H	H	M	H	M					
Weekend_AllDay	H	H	H	H	H	H	H	H	M	M	M	M						
WeekDay_(8 AM-9AM)	H	H	H	H	H	H	H	H	H	M	M	M	M					
WeekDay_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	
WeekDay_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M				
WeekDay_(9PM-10PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	
Weekend_(8AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	
Weekend_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	
Weekend_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	M	M					
Weekend_(9PM-10PM)	H	H	H	H	H	H	H	H	H	H	M	H	H	M	M		M	

Table 15: Summary of Results Showing Correlation of Travel Times and Reliability Indices with the Maximum Travel Time

For Maximum Travel Time																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M			
Saturady_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M		M
Weekday_AllDay	H	H	H	H	H	H	H	H	H	H	M	H	H					
Weekend_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M		M
WeekDay_(8 AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M	H	H
WeekDay_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	M	H	M	M			M	
WeekDay_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M	H	H
WeekDay_(9PM-10PM)	H	H	H	H	H	H	H	H	H	M	M	M	M	M				
Weekend_(8AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M				
Weekend_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H				M	
Weekend_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	M
Weekend_(9PM-10PM)	H	H	H	H	H	H	H	H	H			M	M	M				

Table 16: Summary of Results Showing Correlation of Travel Times and Reliability Indices with the Average Travel Time

For Average Travel Time																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	H					
Saturady_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M		M
Weekday_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	H					
Weekend_AllDay	H	H	H	H	H	H	H	H	H	M	H	H	M	M	M	M		M
WeekDay_(8 AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	H		M	M
WeekDay_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M	
WeekDay_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M		M	M
WeekDay_(9PM-10PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M	
Weekend_(8AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M	
Weekend_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	M		M	M	
Weekend_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	M					
Weekend_(9PM-10PM)	H	H	H	H	H	H	M	H	H	H	H	H	H	M			M	

Table 17*:* Summary of Results Showing Correlation of Travel Times and Reliability Indices with the BT

For Buffer Time																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M
Saturady_AllDay		M	M	M	M	M	M		H	H	H	H	H	H	H	H	H	M
Weekday_AllDay	M	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M
Weekend_AllDay		M	M	M	M	M	M	M	H	H	H	H	H	H	H	H	H	
WeekDay_(8 AM-9AM)	M	H	H	M	M	H	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(12PM-1PM)	H	M	H	H	H	H	H	H	H	H	H	H	H	H	H		H	H
WeekDay_(5PM-6PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(9PM-10PM)	H	M	H	H	H	H	H	H	H	H	H	H	H	H	H	M	H	H
Weekend_(8AM-9AM)	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H		H	H
Weekend_(12PM-1PM)	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H		H	H
Weekend_(5PM-6PM)	M	H	M	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H
Weekend_(9PM-10PM)		M	H	H	H	H	H	H	H	H	H	H	H	H	H		H	H

Table 18: Summary of Results Showing Correlation of Travel Times and Reliability Indices with the BTI

For Buffer Time Index																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay		M							H	H	H	H	H	H	H	H	H	H
Saturady_AllDay			M	M					H	H	H	H	H	H	M	H	H	
Weekday_AllDay								M	H	H	M	H	H	H	H	H	H	H
Weekend_AllDay			M	M					H	H	H	H	H	H		H	H	
WeekDay_(8 AM-9AM)		H	M			M	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(12PM-1PM)	M	M	M	M	M	M	M	M	M	H	H	H	H	H	H	H	H	H
WeekDay_(5PM-6PM)	M	H	M				M	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(9PM-10PM)	M	M	M	M	M	M	M	M	M	H	H	H	H	H	H	H	H	H
Weekend_(8AM-9AM)	M	M	M	M	M	M	M	M	M	H	H	H	H	H	H	H	H	H
Weekend_(12PM-1PM)	M		M	M	M	M	M	M		H	H	H	H	H	H	H	H	H
Weekend_(5PM-6PM)		M						M	H	H	H	H	H	H	H	H	H	H
Weekend_(9PM-10PM)	M	M	M	M	M	M	M	M	M	H	H	H	H	H	H	H	H	H

Table 19*:* Summary of Results Showing Correlation of Travel Times and Reliability Indices with the PTI

For Planning Time Index																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay		M						M	M	H	H	H	H	H	H	H	H	H
Saturady_AllDay		M	M	M	M	M	M	M					H	M	H	M		
Weekday_AllDay								M	M	H	H	H	H	H	H	H	H	H
Weekend_AllDay		M	M	M	M	M	M	M					H		H	M		
WeekDay_(8 AM-9AM)		H	H			M	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(12PM-1PM)	M			M	M					H	H	H	H	H	H		H	H
WeekDay_(5PM-6PM)		H	M			M	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(9PM-10PM)	M			M	M					H	H	H	H	H	H	M	H	H
Weekend_(8AM-9AM)	M			M	M					H	H	H	H	H	H		H	H
Weekend_(12PM-1PM)	M			M	M					H	H	H	H	H	H		H	H
Weekend_(5PM-6PM)		M						M	H	H	H	H	H	H	H	H	H	H
Weekend_(9PM-10PM)	M			M	M					H	H	H	H	H	H		H	H

Table 20: Summary of Results Showing Correlation of Travel Times and Reliability Indices with the TTI

For Travel Time Index																		
	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
Wednesday_AllDay									M	H	H	H	M	H	H	M	H	H
Saturady_AllDay		M	M	M	M	M	M	M	M	M	M		M					H
Weekday_AllDay									M	H	H	H	M	H	H	M	H	H
Weekend_AllDay		M	M	M	M	M	M	M	M	M	M							H
WeekDay_(8 AM-9AM)		H	M			M	H	H	H	H	H	H	H	H	H	M	H	H
WeekDay_(12PM-1PM)				M	M					H	H	H	H	H	H		H	H
WeekDay_(5PM-6PM)		H	M			M	H	H	H	H	H	H	H	H	H	H	H	H
WeekDay_(9PM-10PM)				M						H	H	H	H	H	H		H	H
Weekend_(8AM-9AM)										H	H	H	H	H	H		H	H
Weekend_(12PM-1PM)										H	H	H	H	H	H		H	H
Weekend_(5PM-6PM)		M						M	M	H	H	H	H	H	H		H	H
Weekend_(9PM-10PM)					M					H	H	H	H	H	H		H	H

3.6. Summary of Results

The correlation analysis between travel time and reliability measures was carried by DoW and ToD using data for over 200 links in the Charlotte region. The results from the correlation analysis indicate that the travel time measures are not correlated with the reliability measures in most of the cases.

The average travel time indicates how the selected link is performing. It also provides information about the congestion based on variation of travel rates. This as well as other percentile travel times such as 10^{th} percentile to the 95^{th} percentile travel times discussed in this research are applicable for before and after studies. These cannot be used to compare performance of two links (as length, traffic speed or speed limit, traffic and geometric conditions vary) and use it for allocation of resources.

The travel time variations such as TTV-85, TTV-90 and TTV-95 can be used for the before and after studies as well as comparison of two different links with similar characteristics. On the other hand, measures such as BT and PT are incomparable between different links. These indices are more applicable for the before and after studies.

Among the reliability measures, the BTI, PTI, λ skew, λ variance, and TTI can be used to evaluate the condition of facility (level of congestion or reliability). These can also be used for comparing the performance of one link with the other link. This is helpful to find out the information of one link relative to the other link on the facility.

CHAPTER 4: TWO-DIMENSIONAL PERFORMANCE MEASURE TO ASSESS RELIABILITY OF A LINK

Literature documents various travel time performance measures to assess reliability of a link by ToD and DoW. The variability of travel times can be studied by keeping either ToD and DoW or both of these variables unchanged to reduce the number of dimensions. For example, BTI is a reliability index that is often evaluated keeping ToD and DoW as constants, making it a one dimensional measure i.e., only one variable (in this case WoY) changes and the index for the associated travel times is evaluated. However, if one has to compare the reliabilities of two different days of the week, or reliabilities of Mondays over weekdays, it is not possible using the traditional performance measures. This inability to compare the reliabilities of different groups limits these indices from determining the most reliable groups and the most reliable travel times. Hence, a two-dimensional measure (Cronbach's α) is preferred so that different groups can be compared and reliable groups can be determined

4.1. Introduction of Chronbach's α

In statistics, Cronbach's α is used as a measure of internal consistency or an estimate of reliability of a test. Yu (2001) stated that it is a measure of squared correlation between observed scores and true scores. In other words, Cronbach's α is measured in terms of the ratio of true score variance to observed score variance. The observed score is equal to the true score plus the measurement error. For example, if a student knows 70% of the questions in the test and scores 75%, the additional 5% is because of guessing. In this case, the observed score is 75 while the true score is 70. The additional five points are due to the measurement error, which shows the unreliability of the test. It is assumed that a reliable test should minimize the measurement error so that the error is not highly correlated with the true score. On the other hand, the relationship between true score and observed score should be strong for a test to be a reliable one.

4.2. Assumptions in Estimating Cronbach's α

Several assumptions are made in estimating Cronbach's α.

i) It is assumed that the mean of the measurement error should be zero. Failure of meeting this assumption may lead to an over-estimation of Cronbach's α, though in practice this assumption cannot be fully met (Yu, 2001).
ii) It is also assumed that items must be essentially tau-equivalent, in which the true scores for any two items must be within a constant of each other. If this assumption is violated, Cronbach's α may under-estimate reliability. For this reason, it is generally agreed that Cronbach's α is a lower bound estimate of reliability because perfect essentially tau-equivalence is seldom achieved (Cortina, 1993).

Using simulations, Zimmerman and Zumbo (1993) found that the violations of these assumptions lead to substantive over-estimation and under-estimation of Cronbach's α.

In the current research, travel times are analogous to the test scores. The true scores (expected travel times of the trips) are not fixed as they depend on many factors (ToD, DoW, WoY, etc.). Hence, the mean of the travel times can be taken as the true score while evaluating Cronbach's α for a certain combination of primary and secondary factors (explained in later sections). Thus, the assumptions can be relaxed for the problem in this research.

The following example illustrates the applicability of Cronbach's α. Consider a case where one needs to determine the reliability of three questions in measuring an entity, say, analytical ability of five persons with various educational levels. The test is intended to rate the persons based on their ability to analyze a given dataset. Note that the assumption in this case is that the ability depends on one's education and are testing the reliability of the questions in the test. The results of the test are recorded as shown in Table 21, where scores for questions are recorded as binary variables.

Table 21: Summary of Results from Test Scores

Students	Questions			Total
	Q1	Q2	Q3	
S.1	0	1	1	2
S.2	0	0	1	1
S.3	0	1	0	1
S.4	0	0	1	1
S.5	1	1	1	3
Item Variances	0.2	0.3	0.2	
Variance of Totals				0.8

From Table 21,
Sum of individual variances (V1) = 0.2 + 0.3 + 0.2 = 0.7
Variance of the total scores (V2) = 0.8
Number of questions (items) = 3

For the aforementioned problem, Cronbach's α is computed using the following expression (Cronbach, 1951).

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \sigma_{Y_i}^2}{\sigma_X^2}\right) or \ \frac{K}{K-1}\left(1 - \frac{V1}{V2}\right) \quad \text{Eq. 4.1}$$

$$V1 = \sum_{i=1}^{K} \sigma_{Y_i}^2 \, ; \, V2 = \sigma_X^2 \quad \text{Eq. 4.2}$$

where, K is the number of questions,

σ_X^2 is the variance of the observed total test scores of a person, and,

$\sigma_{Y_i}^2$ is the variance of the sums of scores of a question for all the five persons.

Based on K and computed V1 and V2 from Table 2,

$$\alpha = \frac{3}{3-1}\left(1 - \frac{0.7}{0.8}\right)$$

A 'zero' value of Cronbach's α indicates that the questions doesn't measure the same entity, in this case their analytical ability. On the other hand, if Cronbach's α is 'one', it indicates that all the questions designed did a perfect job. This happens when the scores of a student remain same for all questions making him score either 3 or 0 in total. The computed Cronbach's α in the above example is 0.1875, indicating that the questions are very less reliable in measuring the analytical ability of the person.

In the above example, the persons are the primary source of variance while questions are the

secondary source of variance. In our research, ToD and WoY are considered as sources of variance, both primary and secondary. Taking one combination at a time i.e., Cronbach's α is evaluated once with ToD as primary factor and next with WoY as primary factor. In general, the primary factor causes the changes in the observations and correlation is evaluated over the secondary factor (test items). In summary, Cronbach's α measures the correlation between the results coming from various items i.e., the correlation between the columns in the above table (or simply, it is the correlation of test with itself).

4.3. Data and Computation

The city of Charlotte, North Carolina was considered as the study area. INRIX travel time data for 296 and 311 road links in Charlotte area for the years 2009 and 2010, respectively were gathered and used to illustrate the working of Cronbach's α. A snapshot of raw INRIX data is shown in Figure 4. The 1st column corresponds to the TMC of the link, 2nd column (measurement stamp) gives the date and time (1-minute interval) corresponding to the observed readings. The 3rd and 4th column data are thus extracted from the 2nd column. The 8th column gives the average travel time of all the vehicles recorded in the specific 1-minute interval. DoW and name-of-the-week (NoW) are extracted from the date column and ToD is extracted from the time column. It is to be noted that DoW is another way of representing the NoW where each day is denoted by a number. Sunday is denoted by 1, Monday by 2, and so on.

	tmc_code	measurement_tstamp	Time	Date	Speed	Avg_Speed	Ref_Speed	Travel_Time_Min	confidence_score	cvalue
1	125P04630	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	50	63	65	0.788	30	
2	125P04631	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	66	63	65	0.832	30	
3	125P04632	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	62	61	63	0.527	30	
4	125P04633	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	62	63	65	0.469	30	
5	125P04635	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	64	62	64	0.81	30	
6	125P04636	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	62	63	65	0.402	30	
7	125P04637	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	64	62	65	0.548	30	
8	125P04638	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	64	61	63	0.263	30	
9	125P04639	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	64	62	65	0.449	30	
10	125P04640	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	63	60	63	0.697	30	
11	125P04851	2009-03-09 15:01:08.0	15:01:08.0000000	2009-03-09	48	50	58	0.638	30	
12	125+04629	2009-03-09 15:02:06.0	15:02:06.0000000	2009-03-09	65	63	65	1.846	30	
13	125+04630	2009-03-09 15:02:06.0	15:02:06.0000000	2009-03-09	62	63	64	0.755	30	

Figure 4: Travel Time Data for Every 1-minute Obtained from INRIX

The raw data for the entire year was aggregated for every 30-minute interval to evaluate travel time reliabilities for the study links for every half-hour interval (48 intervals) in a day. The 30-minute interval level aggregated data is as shown in the Figure 5.

	Tmc_Code	YearNum	WeekNum	Timeofday	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_Percentile_10	TT_Percentile_15	TT_Percentile_50	TT_Percentile_85
1	125+04629	2009	1	01:00AM-01:30AM	1.604	2.327	1.86824221183802	1.798	1.826	1.846	1.978
2	125+04629	2009	1	01:00PM-01:30PM	1.626	2.119	1.85807894736843	1.765	1.791	1.854	1.946
3	125+04629	2009	1	01:30AM-02:00AM	1.695	2.327	1.87362246489861	1.771	1.818	1.826	1.978
4	125+04629	2009	1	01:30PM-02:00PM	1.604	2.826	1.86757575757576	1.771	1.791	1.854	1.946
5	125+04629	2009	1	02:00AM-02:30AM	1.626	2.198	1.86600079491258	1.798	1.826	1.846	1.946
6	125+04629	2009	1	02:00PM-02:30PM	1.582	9.89	1.89504469273744	1.765	1.771	1.854	1.946
7	125+04629	2009	1	02:30AM-03:00AM	1.695	2.239	1.88126650755768	1.798	1.826	1.846	1.978
8	125+04629	2009	1	02:30PM-03:00PM	1.582	5.16	1.8787924980048	1.745	1.771	1.846	1.946
9	125+04629	2009	1	03:00AM-03:30AM	1.695	2.282	1.88037460063899	1.826	1.826	1.846	1.978
10	125+04629	2009	1	03:00PM-03:30PM	1.582	2.525	1.85730836653387	1.771	1.798	1.854	1.914
11	125+04629	2009	1	03:30AM-04:00AM	1.745	2.198	1.8823264	1.791	1.818	1.846	1.978
12	125+04629	2009	1	03:30PM-04:00PM	1.582	2.198	1.84821894904459	1.745	1.771	1.846	1.914
13	125+04629	2009	1	04:00AM-04:30AM	1.626	2.158	1.87986512370312	1.826	1.826	1.846	1.978

Figure 5: Travel Time Data Aggregated for Every 30-minute Interval

It can be observed that all the readings are aggregated into 30-minute intervals (column 4). Note that Column 3 i.e., WeekNum is same as the DoW. The average travel time and 85th percentile travel time are computed using the travel time data and are shown in columns 8 and 9. Once the data is aggregated, it was then used to evaluate Cronbach's α using equations 4.1 and 4.2.

Cronbach's α (travel time reliability) was then measured on the basis of various categories of travel times (DoW, weekend/weekday, ToD, etc.). A sample data for the year 2009 and for 'Monday' category travel times (85th percentile) are shown in Table 22. In the table, the first row 'WoY' corresponds to the secondary factor and the first column 'ToD' corresponds to the primary factor i.e., the travel time is expected to vary with ToD and is checked for the consistency/reliability over the 52 weeks of a given year. A higher value of α is obtained when the travel times over the day are well correlated between the 52 weeks of the year. The maximum of '1' is obtained when all the 52 weeks have identical travel times for any time interval of the day (maintaining certain variance within the various time intervals of the day). The Cronbach's α is compared by changing the primary and secondary factors (such as transposing rows and columns in Table 22), and the most reliable groups that gives best expected travel times are identified.

Table 22: Sample Travel Time Data of a Link and Day-of-the-week (DoW) Used for Computing 'α'

ToD (Primary factor)	WoY (secondary factor)							Sum of travel times
	Week 1	Week 2	Week 3	.	.	.	Week 52	
12:00 AM-12:30 AM	1.826	1.914	1.914	.	.	.	.	96.72
12:30 AM-1:00 AM	1.914	1.946	2.046	.	.	.	.	99.23
1:00 AM-1:30 AM	1.884	2.239	1.884	.	.	.	.	100.28
1:30 AM-2:00 AM	1.978	1.826	1.914	.	.	.	.	92.56
2:00 AM-2:30 AM	1.854	1.826	1.946	.	.	.	.	96.83
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
11:30 PM-12:00 AM	1.726	1.926	2.027	.	.	.	.	101.23
Item Variance	0.001	0.012	0.021	.	.	.	.	

4.5. Case Study

A 2-mile section of freeway on I-85 Northbound direction in the city of Charlotte, North Carolina with TMC code '125+04629' was considered as the case study to illustrate the working of the methodology. Travel time data for the year 2009 was considered to evaluate reliability based on two categories - DoW and weekday/weekend. Two different travel time measures, 85th percentile travel times and average travel times, were also considered to see which of the two travel time measures are more reliable in making an expectation of travel time. This will yield eight categories of Cronbach's α values as summarized in Table 23.

Table 23: Characteristics of Each Category of Cronbach's 'α'

	Category	Primary factor	Secondary factor	Travel Time Measure Used
α1	DoW	ToD	WoY	85th Percentile
α2	Weekday/Weekend	ToD	WoY	85th Percentile
α3	DoW	WoY	ToD	85th Percentile
α4	Weekday/Weekend	WoY	ToD	85th Percentile
α5	DoW	ToD	WoY	Average
α6	Weekday/Weekend	ToD	WoY	Average
α7	DoW	WoY	ToD	Average
α8	Weekday/Weekend	WoY	ToD	Average

The step-by-step procedure for evaluating Cronbach's α for a TMC code is discussed next.

Step 1: Evaluating Variance 1 (V1)
As mentioned in the example problem used in explaining Cronbach's alpha, Variance 1 (V1) is the defined as the sum of all the item variances. In the current example, the variance of all the travel times corresponding to any given WoY is the item variance of that WoY. All the item variances are shown in the bottom-most row in the Table 22. Hence, the sum of all the cells in the bottom-most row gives the Variance 1 (V1) for the considered problem.

Step 2: Evaluating Variance 2 (V2)
Variance 2 (V2) is the variance of all the sum of the scores (in this case, sum of the travel times). The sum of the travel times are shown in the right-most column in Table 22. The computed variance of all the cells in this column results in Variance 2 (V2).

Step 3: Evaluating Cronbach's α
Cronbach's α is then computed using Variance 1 (V1) and Variance 2 (V2) from steps 1 and 2. Note that the value of N is 52 in this example. The obtained Cronbach's α is the reliability score for the TMC code '125+04629' for Monday trips, with primary factor as ToD and using 85^{th} percentile travel times. The same method was applied for all the links using SQL and the variance values are obtained for every TMC and every WoY as shown in Figure 6. The (a) and (b) parts of the Figure 6 show the variance values for trips by WoY, whereas (c) and (d) show the variance values for weekday/weekend category trips. It can be noticed that each TMC has 7 values for variance, one for each day (Sunday to Saturday) in the case of (a) and (b) whereas (c) and (d) has only two values (one for a weekday where wd=1 and the other for weekend where wd=0).

	Tmc_Code	WeekNum	Variance1
1	125+04629	1	0.787663118489601
2	125+04629	2	325.959773625665
3	125+04629	3	90.3749080684376
4	125+04629	4	55.3980268744632
5	125+04629	5	50.4352679299929
6	125+04629	6	15.1608850017314
7	125+04629	7	220.575815691639
8	125+04630	1	0.251765258680552
9	125+04630	2	6.0735552328803
10	125+04630	3	0.352447705504659

(a)

	Tmc_Code	WeekNum	Variance2
1	125+04629	1	1.31080608966295
2	125+04629	2	490.544851305426
3	125+04629	3	138.440957262028
4	125+04629	4	108.437931085073
5	125+04629	5	88.628840524759
6	125+04629	6	37.3944818372911
7	125+04629	7	284.714168559857
8	125+04630	1	0.610629230394807
9	125+04630	2	8.50057329365366
10	125+04630	3	1.05607943999136

(b)

	Tmc_Code	wd	Variance1
1	125+04629	0	55.4070769156901
2	125+04629	1	21.1369998669426
3	125+04630	0	0.533202743164064
4	125+04630	1	2.08605544948315
5	125+04631	0	5.94362076671007
6	125+04631	1	15.3638660871179
7	125+04632	0	7.20454829372831
8	125+04632	1	6.86098834711359
9	125+04633	0	1.26594267567274
10	125+04633	1	2.14493755253605

(c)

	Tmc_Code	wd	Variance2
1	125+04629	0	66.7398854108057
2	125+04629	1	32.7491097093177
3	125+04630	0	1.11133204792319
4	125+04630	1	2.67980573514221
5	125+04631	0	9.02441576400209
6	125+04631	1	27.1267256182327
7	125+04632	0	18.6164786240091
8	125+04632	1	17.8828797115566
9	125+04633	0	3.56438079992813
10	125+04633	1	4.87137485873579

(d)

Figure 6: Variance Calculated for Day-of-the-week (DoW) and Weekday/Weekend Category Trips

Similarly, the primary and secondary factors can be interchanged to obtain new values for Variance 1 (V1) and Variance 2 (V2), and hence, Cronbach's α (referred to as α2). If the average travel times are used in the place of 85th percentiles, α5 and α6 can be obtained.

Cronbach's α computed for each of combinations and their interpretations are discussed next.

4.5.1. Cronbach's α Computed for the 'Day-of-the-week (DoW)' Category with 'Week-of-the-year (WoY)' as Primary Factor (α3, α7)

'WoY' is considered as the primary factor and Cronbach's α is computed for every 'DoW' (category). In this case, the assumption is that the primary source of variation in travel times on the link is the WoY associated with the trip. For each DoW, the corresponding values of Cronbach's α (α3 and α7) are mentioned in Table 24.

From Table 24, Mondays are least reliable with this combination while Thursdays are the most reliable. Table 25 summarizes the thresholds to determine the level of reliability. They are same as those used in other studies related to Cronbach's α (George, 2003; Kline, 2000).

Table 24: Cronbach's 'α's Associated for Varying Categories, Primary and Secondary Factors for a TMC

TMC Code	DOW	WD	α1	α2	α3	α4	α5	α6	α7	α8	Max(α)
125+04629	1	0	0.41	0.17	0.53	**0.68**	0.58	0.18	0.62	0.63	0.68
125+04629	2	1	0.34	0.36	0.12	0.62	0.37	0.38	0.15	**0.67**	0.67
125+04629	3	1	0.35	0.36	0.52	0.62	0.38	0.38	0.57	**0.67**	0.67
125+04629	4	1	0.50	0.36	**0.75**	0.62	0.31	0.38	0.69	0.67	0.75
125+04629	5	1	0.44	0.36	0.60	0.62	0.38	0.38	0.58	**0.67**	0.67
125+04629	6	1	0.61	0.36	0.49	0.62	0.61	0.38	0.57	**0.67**	0.67
125+04629	7	0	0.23	0.17	0.67	**0.68**	0.25	0.18	0.62	0.63	0.68

*DOW stands for DoW with Sunday coded as 1, Monday as 2, and so on
*WD represents weekday, coded with 1 for weekday and 0 for weekend

Table 25: Reliability Thresholds to Determine the Level of Reliability

Cronbach's α	Level of Reliability
≥ 0.9	A (Excellent)
0.7 – 0.9	B (Highly Reliable)
0.5 – 0.7	C (Reliable)
0.4 – 0.5	D (Poorly Reliable)
<0.4	E (Unreliable)

4.5.2. Cronbach's α Computed for the 'Day-of-the-week (DoW)' Category with 'Time-of-the-day (ToD)' as Primary Factor

Here, ToD is considered as the primary factor to evaluate the reliability score (Cronbach's α). Hence, the assumption in this case is that the primary variance in the travel times is due to the ToD associated with each trip. Table 24 shows Cronbach's α (α1 and α5) for each DoW based on varying ToD. None of the values are greater than 0.7, which indicates that this combination does not work for any of the seven days-of-the-week.

4.5.3. Cronbach's α Computed for the 'Weekday/Weekend' Category with Varying Primary Factors

The results found after aggregation of data for weekday and weekend are shown as α2, α4, α6, α8 in Table 24. The primary and secondary factors as well as the travel time statistic associated with each Cronbach's α are shown in Table 23.

4.5.4. Obtaining Most Reliable Travel Time of a Trip

The evaluated Cronbach's α values are used in estimating the most reliable travel time of any trip on a link. As an example, a motorist wants to make a travel plan on 11th of April 2015 between

10:00 AM to 10:30 AM on the above mentioned TMC and wants to know his/her travel time. The tool developed from this study uses the following steps to make an expectation.

1) Identify the DoW, which is Saturday, a weekend.
2) Identify the WoY, which is 15th WoY 2015.
3) Select the maximum Cronbach's α and note the associated combination.

In this case, α4 is the highest implying that the category is weekend and the travel time is WoY dependent (refer Table 22). Hence, one has to take the average of the 85th percentile travel times observed for the weekend category trips for the 15th WoY. The result gives the expected travel time of the trip. Figure 6 shows the expected travel times for weekend category based on the 2009 data with primary factor as 'WoY'. The expected travel time depends on the WoY with each point representing for each WoY in Figure 7 (total 52 points). Since the data is not available for the first 9 weeks of the year, one does not see any points corresponding to them. This shows the limitation of this approach which is further explained in the later sections. However, the basic idea is to compute the Cronbach's α for all the combinations and take the maximum of these 8 values for any day and then compute the most reliable travel time for any trip.

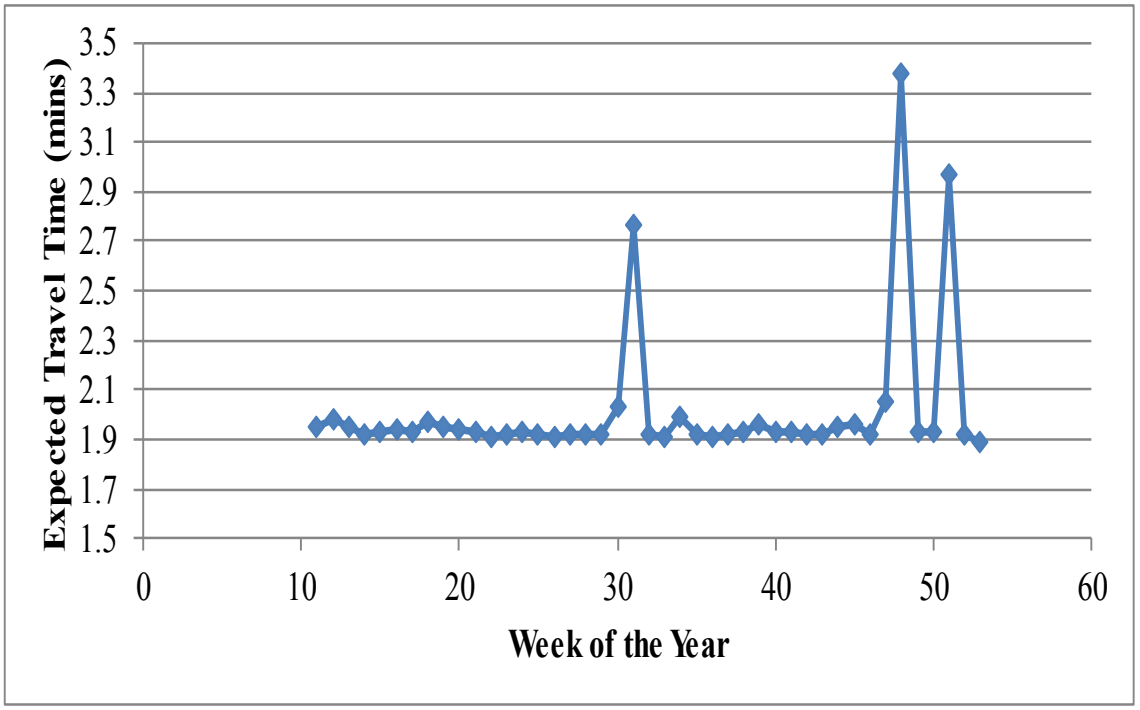


Figure 7: Expected Travel Times for Varying Week-of-the-year (WoY)

4.6. Analysis of All Links in the Study Area (Network)

The above analysis to evaluate link-level reliability was applied to all the links considered in the study (296 links for the year 2009 and 311 links for the year 2010). The results obtained are summarized in Table 26. Ranking the links with these reliability scores (the maximum of the 8 scores is taken for a link) help the motorist choose his/her route from various alternatives. Also, the planning agencies can identify the most unreliable links and make necessary recommendations to improve transportation system performance using this information.

Table 28 shows the percentage of cases (2,072 cases for 2009 and 2,177 cases for 2010) that are reliable for a particular combination associated within Cronbach's α. Table 26 and Table 27 show the percentage of links that are reliable for every combination within Cronbach's α evaluated for each DoW. A majority of the trips have a higher value of Cronbach's α when the average travel times are taken instead of the 85th percentile values. This can be attributed to the fact that the data used in the study primarily deals with recurring congestion (if present) and hence not resulting in over-estimation of travel time and reliability. Also, weekday/weekend category grouping is beneficial for a majority of the weekend trips. This implies that one need not worry about the DoW but just see if it is a weekday or a weekend to plan a reliable trip. This might be because the travel time on a weekend is not much affected by the ToD as traffic levels are almost equally spread over the day, whereas during weekdays, ToD is quite defining the travel time. The same trend can also be observed when the analysis is applied to all cases as shown in Table 28. However, there is no need to generalize here as every link has its own reliable combination to evaluate its reliable travel times.

Table 26: Percentage of links with Maximum Corresponding '*α*' Values for the year 2009

	α1	α2	α3	α4	α5	α6	α7	α8
Sunday	3.72	4.05	2.36	5.07	10.14	16.22	14.19	44.26
Monday	0.34	13.18	0.34	1.35	3.04	38.51	5.41	37.84
Tuesday	2.36	11.49	4.73	1.01	3.72	35.14	6.42	35.14
Wednesday	0.00	11.15	2.70	1.69	4.05	35.14	6.76	38.51
Thursday	0.00	11.82	1.01	1.69	6.08	35.47	5.74	38.18
Friday	4.39	11.49	0.34	1.35	7.09	33.45	11.15	30.74
Saturday	4.73	3.72	2.70	4.39	10.47	15.54	28.04	30.41

Table 27: Percentage of Links with Maximum Corresponding 'α' Values for the year 2010

	α1	α2	α3	α4	α5	α6	α7	α8
Sunday	0.64	3.86	2.25	24.44	7.07	27.33	6.43	27.97
Monday	0.32	9.00	0.32	4.50	5.47	66.24	2.57	11.58
Tuesday	0.64	9.32	0.32	4.18	9.00	62.06	4.82	9.65
Wednesday	0.00	9.32	0.32	4.50	12.86	60.13	2.25	10.61
Thursday	0.00	9.65	0.00	5.14	11.25	61.74	2.57	9.65
Friday	0.32	9.32	0.64	3.22	12.22	60.45	3.22	10.61
Saturday	0.64	2.57	4.82	1.93	6.11	20.26	47.91	15.76

Table 28: Percentage of Cases with Maximum Corresponding 'α' Values

Cronbach's Coefficient	Percent of Cases Reliable (2009)	Percent of Cases Reliable (2010)
α1	2.22	0.37
α2	9.56	7.58
α3	2.03	1.24
α4	2.36	6.84
α5	6.37	9.14
α6	29.92	51.17
α7	11.10	9.97
α8	36.44	13.69

4.6.1. Level of Reliability based on Cronbach's α

Cronbach's α was used as a performance measure to classify the links/corridors into various LOS categories. Since it is a correlation coefficient, the same threshold values that are used to determine the level of dependence (linear) for various level of reliability classification were used. Table 25 shows the level of reliability classification of any link based on Cronbach's α. If any of the Cronbach's α is greater than 0.9, the link is said to be very highly reliable for the associated combination and one can expect the value to be at least greater than 0.7 to comment on its reliability.

Analysis was performed in this study, covering 296 and 311 links in the city of Charlotte, North Carolina for the year 2009 and 2010, respectively, consisting around 2,072 and 2177 different combinations based on DoW (296*7 = 2,072 & 311*7 = 2177). The percent of these

cases evaluated for each combination of Cronbach's α falling in various level of reliability category are shown in Table 29. Overall, results shows that about 85% of the links are highly reliable (level of reliability A or B) while 1.2% of links are unreliable. This means that travel times follow certain trends and are predictable in 85% of the cases. The trip durations (travel time of the trip) may be ToD dependent, WoY dependent or category of trip (weekday/weekend or DoW) dependent. Some trips are reliable by using 85th percentile travel time while others are reliable from average travel time point of view. The ability of this new approach in identifying the reliable category from among eight combinations and also identifying the factor causing the variability helps in observing these trends. Since multiple factors are considered unlike in traditional measures, where only ToD is considered, a reliable group is identified for each type of combination.

Table 29: Percentages of Cases Falling in Each Level of Reliability

Cronbach's α Combination	Year	Percentage of cases with reliability level				
		A	B	C	D	E
α1	2010	18.65	12.59	13.37	20.53	34.86
	2009	10.81	12.84	13.71	28.52	34.12
α2	2010	27.97	12.22	11.41	19.29	29.10
	2009	17.57	10.81	13.85	31.08	26.69
α3	2010	4.78	7.58	15.43	39.00	33.21
	2009	6.66	8.16	12.74	33.06	39.38
α4	2010	4.34	14.47	28.94	34.73	17.52
	2009	12.84	12.84	16.22	34.63	23.48
α5	2010	26.96	19.66	13.92	17.36	22.09
	2009	13.75	13.71	15.30	26.98	30.26
α6	2010	36.01	17.68	15.27	13.50	17.52
	2009	20.44	13.34	18.58	23.48	24.16
α7	2010	7.44	10.24	17.87	40.61	23.84
	2009	14.09	13.90	14.43	29.87	27.70
α8	2010	7.88	20.74	28.30	31.83	11.25
	2009	27.87	15.71	15.71	25.51	15.20

4.6.2. Cronbach's α and Traditional Reliability Measures

With Cronbach's α measuring the reliability of the link at macro-level and identifying the most reliable base group (category) that closely predicts the travel time, one can use these base groups to compute the traditional reliability measures i.e., BTI and PTI at micro-level. For example, if it is found that weekend travel times are more consistent when the primary factor is the WoY, then BTIs can be evaluated for each WoY. It can be observed that these BTIs will be much lower than the BTIs that are computed with ToD as the base group (category). Lower BTIs imply that those set of travel times are more consistent within themselves. This way Cronbach's α can be used to compute lower BTIs by changing their base groups or combinations. This also serves as the justification of this study.

Figure 8 shows the comparison of the BTIs evaluated for different values of Cronbach's α for

the same example discussed earlier. While calculating BTI, only 4 cases arise instead of 8 (since BTI needs only these categories). Figure 8(a) and Figure 8(c) represent the BTIs for the trips for every 30-minute interval of the day (ToD category). While Figure 8(a) represents Saturday, Figure 8(c) represents weekend. Similarly, Figure 8(b) and Figure 8(d) are for WoY category. Where, Figure 8(b) represents Saturday and Figure 8(d) represents weekend. From Table 23, since α4 and α8 values are 0.68 and 0.63, respectively which are with the combination of 'weekend' category and 'WoY' as primary factor, the associated BTIs are seen close to zero in Figure 8(d) than the others. One can compare these with the BTIs associated with minimum Cronbach's α values (α2 and α4) i.e., Figure 8(b). The number of BTIs greater than 10 is more in this case than any of the other three cases. This reinforces the concept of Cronbach's α when compared to the traditional reliability measures.

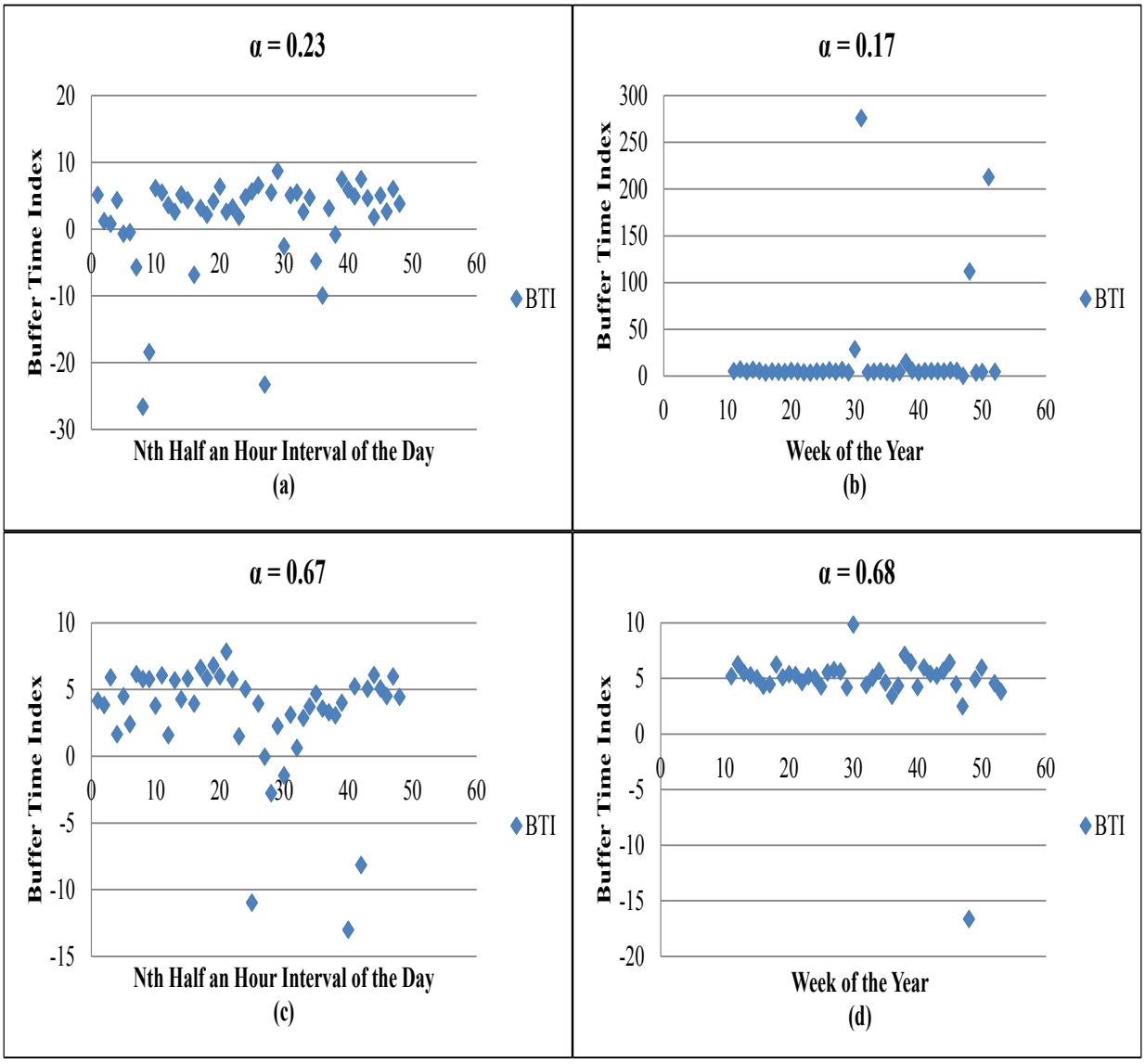


Figure 8: Comparison of BTIs Evaluated by Category of Trips

4.7. Summary and Limitations of the Proposed Performance Measure

A new reliability measure, Cronbach's α, is proposed to assess reliability of links in the transportation network. This performance measure acts as a macro-level measure of reliability that evaluates the level of consistency of travel times. The proposed reliability measure was found to be a better estimator of expected travel times as compared to the traditional travel time performance measures such as BTI and PTI, which are often evaluated for fixed criteria (ToD). This is because the proposed macroscopic measure evaluated reliability not only for a ToD over the year but also for a WoY over the ToD and using both 85^{th} percentile travel times as well as average travel times from the historical data. The reliabilities that are evaluated at link-level helps identify the most unreliable links in the network.

Data availability is one of the major requirements for accurate estimates of reliability scores. The formula to evaluate Cronbach's α uses Variance 1 (V1) which is the sum of item variances and Variance 2 (V2) which is the variance of total scores. The lower the ratio of Variance 1 (V1) to Variance (V2), the higher is Cronbach's α. It is to be noted that lower value of Variance (V1) should automatically reflect lower value of Variance (V2) because when individual values are closer to each other, the sums of those scores should also be closer unless and until some values are missing. In case of missing fields, an over-estimation or under-estimation of Cronbach's α is observed. If the Variance 2 (V2) can be adjusted when missed data is observed, the results can be more credible. To combat this, a method where the total scores are proportionately increased when some values are missing was used in this research. The proposed method has fixed the issue to a high extent though there might be little over-estimation or under-estimation in case of missing fields.

CHAPTER 7: CONCLUSIONS

Delays in a transportation network are almost inevitable with the growing congestion in urban areas. Motorists are more interested in knowing their expected travel time along a link when planning a trip so as to reach their destination within the desired time, rather than completing a trip in the time that one would ideally take to travel on the network. Hence, reliability of a link is crucial to both the motorists and practitioners of transportation systems.

Results from the evaluation of various performance measures indicate that the average travel time is correlated with all the travel time and the three travel time variations related measures. The BT is the only measure that is correlated with almost every other measure used in the analysis. The BT is the difference of 95th percentile travel time and the average travel time. It could be used as the reliability measure for before and after studies.

BTI is another reliability measure that depends on the average travel time. It is defined as the ratio of difference in 95th percentile travel time to the average travel time to the average travel time. This measure is correlated with almost all the reliability measures. It is therefore recommended as the best reliability measure for evaluating the condition of the facility. Since it is calculated as an index, BTI can also be used for comparing the performance of any two links in the network. It also provides adequate information about the congestion or level of reliability of the facility or the link.

A new reliability measure, Cronbach's α, was proposed to assess reliability of links in the transportation network. This performance measure acts as a macro-level measure of reliability that evaluates the level of consistency of travel times. The proposed reliability measure was found to be a better estimator of expected travel times as compared to the traditional travel time performance measures such as BTI and PTI, which are often evaluated for fixed criteria (ToD). This is because the proposed macroscopic measure evaluated reliability not only for a ToD over the year but also for a WoY over the ToD and using both 85th percentile travel times as well as average travel times from the historical data. The reliabilities are evaluated at link-level which also helps identify the most unreliable links in the network.

Overall, results obtained indicate that the mean travel time estimates of the trips aggregated for any time interval from the data are more reliable than compared to 85th percentile travel times. Also, weekend trips are not time dependent but are WoY dependent whereas weekday trips are time dependent in most of the cases. Results also indicate that missing field in the data might result in over-/under-estimation of results. Along with identifying the reliable travel times and reporting absolute reliable scores of the links, a new LOS criteria based on reliability scores is proposed. However, a link with LOS 'A' from this study does not mean a perfect case, as the travel times associated might still be very high just that they are reliable and recurring.

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APPENDIX

Table A-1: Performance Measures Correlation Matrix (2009) - Monday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.92	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.41	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.41	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.48	0.96	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.76	0.66	0.95	0.77	0.77	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.69	0.68	0.91	0.70	0.70	0.77	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.61	0.76	0.86	0.62	0.62	0.69	0.94	0.96	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.23	0.63	0.58	0.24	0.24	0.35	0.80	0.86	0.86	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.62	0.58	0.24	0.24	0.34	0.80	0.86	0.85	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.25	0.73	0.59	0.26	0.26	0.35	0.77	0.83	0.92	0.94	0.93	1.00	-	-	-	-	-	-
BT	0.24	0.73	0.58	0.25	0.25	0.34	0.74	0.80	0.91	0.92	0.90	1.00	1.00	-	-	-	-	-
BTI	-0.05	0.55	0.22	-0.04	-0.04	0.03	0.36	0.43	0.60	0.61	0.58	0.75	0.77	1.00	-	-	-	-
PTI	-0.05	0.57	0.25	-0.04	-0.04	0.05	0.43	0.50	0.62	0.71	0.69	0.77	0.78	0.94	1.00	-	-	-
λ Skew	-0.03	0.31	0.14	-0.03	-0.03	-0.02	0.29	0.34	0.38	0.49	0.47	0.48	0.49	0.64	0.63	1.00	-	-
λ Var	-0.05	0.49	0.24	-0.05	-0.05	0.03	0.46	0.54	0.57	0.76	0.74	0.73	0.72	0.80	0.90	0.82	1.00	-
TTI	-0.07	0.54	0.25	-0.07	-0.06	0.05	0.44	0.51	0.58	0.74	0.73	0.74	0.72	0.81	0.95	0.53	0.89	1.00

Table A-2: Performance Measures Correlation Matrix (2009) - Monday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.36	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.41	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.36	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.36	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.36	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.37	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.37	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.92	0.48	0.95	0.93	0.93	0.93	0.94	0.94	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.56	0.27	0.60	0.56	0.56	0.57	0.67	0.68	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.47	0.21	0.51	0.47	0.48	0.48	0.59	0.59	0.56	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.29	0.48	0.35	0.29	0.29	0.29	0.34	0.34	0.63	0.49	0.45	1.00	-	-	-	-	-	-
BT	0.21	0.40	0.27	0.22	0.22	0.22	0.26	0.27	0.57	0.42	0.38	0.99	1.00	-	-	-	-	-
BTI	-0.14	0.17	-0.09	-0.14	-0.14	-0.14	-0.07	-0.06	0.19	0.35	0.36	0.77	0.79	1.00	-	-	-	-
PTI	-0.16	0.19	-0.10	-0.16	-0.15	-0.15	-0.07	-0.06	0.15	0.43	0.45	0.71	0.72	0.97	1.00	-	-	-
λ Skew	-0.07	0.00	-0.04	-0.07	-0.07	-0.08	0.06	0.06	0.06	0.71	0.80	0.29	0.27	0.48	0.60	1.00	-	-
λ Var	-0.18	-0.04	-0.15	-0.18	-0.18	-0.18	-0.05	-0.05	-0.04	0.65	0.72	0.27	0.25	0.56	0.69	0.93	1.00	-
TTI	-0.24	0.21	-0.19	-0.24	-0.23	-0.23	-0.15	-0.14	-0.03	0.38	0.42	0.42	0.40	0.69	0.83	0.57	0.75	1.00

Table A-3: Performance Measures Correlation Matrix (2009) - Monday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.45	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.84	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.48	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.49	0.87	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.88	0.64	0.97	0.90	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.68	0.72	0.96	0.70	0.71	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.63	0.74	0.94	0.66	0.67	0.87	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.55	0.77	0.89	0.59	0.60	0.78	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.21	0.66	0.69	0.24	0.26	0.57	0.86	0.89	0.91	1.00	-	-	-	-	-	-	-	-
TTV_85	0.20	0.64	0.68	0.23	0.25	0.57	0.86	0.88	0.88	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.21	0.71	0.68	0.25	0.27	0.53	0.83	0.87	0.93	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.20	0.67	0.64	0.24	0.25	0.48	0.79	0.84	0.92	0.94	0.90	0.99	1.00	-	-	-	-	-
BTI	-0.16	0.35	0.12	-0.14	-0.13	-0.02	0.22	0.29	0.42	0.46	0.41	0.56	0.61	1.00	-	-	-	-
PTI	-0.13	0.43	0.26	-0.10	-0.09	0.11	0.42	0.47	0.56	0.67	0.64	0.71	0.73	0.93	1.00	-	-	-
λ Skew	-0.10	0.17	0.03	-0.09	-0.09	-0.08	0.12	0.16	0.23	0.26	0.23	0.32	0.36	0.68	0.60	1.00	-	-
λ Var	-0.15	0.32	0.17	-0.13	-0.12	0.01	0.33	0.38	0.46	0.57	0.54	0.61	0.64	0.88	0.94	0.77	1.00	-
TTI	-0.11	0.51	0.34	-0.08	-0.06	0.22	0.52	0.57	0.61	0.78	0.77	0.77	0.74	0.77	0.94	0.47	0.85	1.00

Table A-4: Performance Measures Correlation Matrix (2009) - Monday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.29	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.32	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.29	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.29	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.30	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.30	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.31	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.32	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.72	0.33	0.76	0.73	0.73	0.76	0.78	0.78	0.79	1.00	-	-	-	-	-	-	-	-
TTV_85	0.62	0.32	0.67	0.63	0.63	0.67	0.69	0.69	0.69	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.63	0.38	0.67	0.64	0.64	0.66	0.68	0.69	0.73	0.88	0.82	1.00	-	-	-	-	-	-
BT	0.62	0.18	0.64	0.63	0.62	0.63	0.65	0.66	0.70	0.75	0.63	0.93	1.00	-	-	-	-	-
BTI	-0.18	-0.17	-0.17	-0.17	-0.18	-0.18	-0.16	-0.14	-0.11	0.12	0.05	0.29	0.42	1.00	-	-	-	-
PTI	-0.29	-0.02	-0.26	-0.29	-0.29	-0.27	-0.26	-0.25	-0.23	0.06	0.08	0.16	0.11	0.74	1.00	-	-	-
λ Skew	-0.08	-0.04	-0.09	-0.08	-0.09	-0.10	-0.08	-0.06	-0.06	0.10	0.01	0.13	0.22	0.45	0.20	1.00	-	-
λ Var	-0.31	-0.07	-0.28	-0.31	-0.30	-0.28	-0.27	-0.26	-0.26	0.14	0.14	0.08	0.03	0.68	0.89	0.29	1.00	-
TTI	-0.31	0.13	-0.27	-0.31	-0.30	-0.28	-0.27	-0.27	-0.27	0.02	0.10	0.03	-0.14	0.29	0.85	-0.04	0.75	1.00

Table A-5: Performance Measures Correlation Matrix (2009) - Wednesday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.43	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.92	0.69	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.44	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.44	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.55	0.97	0.97	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.76	0.76	0.95	0.76	0.77	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.69	0.79	0.91	0.70	0.70	0.81	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.61	0.83	0.87	0.62	0.62	0.74	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.23	0.76	0.59	0.24	0.25	0.41	0.81	0.87	0.90	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.74	0.59	0.24	0.24	0.41	0.81	0.86	0.88	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.80	0.60	0.25	0.26	0.41	0.79	0.86	0.92	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.23	0.78	0.58	0.24	0.24	0.38	0.77	0.84	0.91	0.97	0.94	1.00	1.00	-	-	-	-	-
BTI	-0.05	0.54	0.22	-0.05	-0.04	0.05	0.39	0.47	0.59	0.67	0.63	0.75	0.78	1.00	-	-	-	-
PTI	-0.05	0.57	0.25	-0.04	-0.04	0.08	0.44	0.52	0.61	0.73	0.71	0.78	0.79	0.94	1.00	-	-	-
λ Skew	-0.03	0.32	0.12	-0.03	-0.03	-0.02	0.26	0.32	0.39	0.45	0.41	0.50	0.54	0.78	0.66	1.00	-	-
λ Var	-0.06	0.53	0.22	-0.06	-0.06	0.04	0.41	0.49	0.57	0.70	0.68	0.74	0.76	0.93	0.95	0.82	1.00	-
TTI	-0.07	0.57	0.25	-0.07	-0.06	0.09	0.45	0.51	0.59	0.74	0.73	0.76	0.75	0.83	0.96	0.50	0.87	1.00

Table A-6: Performance Measures Correlation Matrix (2009) - Wednesday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.44	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.46	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.43	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.43	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.43	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.43	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.43	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.44	0.98	0.98	0.98	0.98	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.58	0.27	0.61	0.58	0.58	0.59	0.69	0.69	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.49	0.22	0.53	0.49	0.50	0.50	0.61	0.61	0.60	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.45	0.26	0.49	0.45	0.45	0.45	0.52	0.53	0.63	0.73	0.71	1.00	-	-	-	-	-	-
BT	0.31	0.07	0.34	0.31	0.31	0.32	0.38	0.39	0.50	0.61	0.60	0.95	1.00	-	-	-	-	-
BTI	-0.19	-0.13	-0.17	-0.19	-0.19	-0.19	-0.11	-0.11	0.00	0.34	0.38	0.70	0.80	1.00	-	-	-	-
PTI	-0.19	-0.04	-0.16	-0.19	-0.19	-0.19	-0.10	-0.10	0.00	0.41	0.46	0.70	0.74	0.95	1.00	-	-	-
λ Skew	-0.08	-0.03	-0.05	-0.08	-0.08	-0.08	0.05	0.05	0.05	0.71	0.79	0.48	0.46	0.57	0.65	1.00	-	-
λ Var	-0.19	-0.07	-0.15	-0.19	-0.19	-0.19	-0.06	-0.06	-0.06	0.63	0.71	0.42	0.41	0.65	0.75	0.94	1.00	-
TTI	-0.24	0.11	-0.20	-0.24	-0.24	-0.24	-0.16	-0.16	-0.12	0.35	0.40	0.40	0.33	0.60	0.80	0.58	0.75	1.00

Table A-7: Performance Measures Correlation Matrix (2009) - Wednesday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.33	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.77	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.37	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.95	0.37	0.89	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.81	0.54	0.99	0.90	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.63	0.66	0.97	0.73	0.76	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.58	0.68	0.95	0.68	0.71	0.90	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.48	0.71	0.90	0.59	0.62	0.83	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.22	0.68	0.76	0.34	0.38	0.67	0.88	0.92	0.95	1.00	-	-	-	-	-	-	-	-
TTV_85	0.21	0.68	0.75	0.33	0.37	0.68	0.88	0.91	0.93	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.20	0.70	0.73	0.31	0.35	0.63	0.85	0.90	0.95	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.19	0.68	0.71	0.29	0.33	0.60	0.83	0.88	0.94	0.97	0.95	1.00	1.00	-	-	-	-	-
BTI	-0.21	0.29	0.09	-0.17	-0.15	-0.02	0.19	0.27	0.38	0.44	0.38	0.52	0.56	1.00	-	-	-	-
PTI	-0.18	0.44	0.19	-0.14	-0.12	0.08	0.33	0.40	0.50	0.59	0.56	0.64	0.67	0.92	1.00	-	-	-
λ Skew	-0.13	0.09	-0.03	-0.13	-0.13	-0.11	0.04	0.10	0.15	0.20	0.15	0.23	0.27	0.64	0.54	1.00	-	-
λ Var	-0.19	0.27	0.10	-0.15	-0.14	-0.01	0.22	0.29	0.37	0.46	0.41	0.50	0.53	0.89	0.90	0.75	1.00	-
TTI	-0.17	0.53	0.25	-0.12	-0.10	0.14	0.40	0.46	0.54	0.65	0.65	0.68	0.69	0.79	0.95	0.42	0.82	1.00

Table A-8: Performance Measures Correlation Matrix (2009) - Wednesday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.43	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.47	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.43	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.43	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.43	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.43	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.44	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.45	0.99	0.98	0.98	0.98	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.54	0.30	0.59	0.55	0.55	0.55	0.66	0.66	0.66	1.00	-	-	-	-	-	-	-	-
TTV_85	0.41	0.22	0.45	0.41	0.41	0.42	0.53	0.53	0.53	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.58	0.36	0.62	0.58	0.58	0.59	0.66	0.67	0.72	0.86	0.80	1.00	-	-	-	-	-	-
BT	0.48	0.15	0.50	0.48	0.48	0.48	0.55	0.56	0.62	0.77	0.73	0.94	1.00	-	-	-	-	-
BTI	-0.15	-0.11	-0.13	-0.15	-0.16	-0.16	-0.05	-0.05	-0.02	0.52	0.59	0.50	0.59	1.00	-	-	-	-
PTI	-0.19	0.00	-0.15	-0.19	-0.19	-0.18	-0.08	-0.08	-0.06	0.54	0.63	0.46	0.46	0.90	1.00	-	-	-
λ Skew	-0.05	-0.02	-0.02	-0.05	-0.05	-0.06	0.08	0.07	0.06	0.70	0.80	0.48	0.50	0.73	0.76	1.00	-	-
λ Var	-0.17	-0.03	-0.14	-0.17	-0.17	-0.17	-0.05	-0.05	-0.05	0.64	0.74	0.43	0.43	0.84	0.92	0.91	1.00	-
TTI	-0.22	0.14	-0.17	-0.22	-0.22	-0.20	-0.14	-0.14	-0.12	0.35	0.41	0.28	0.16	0.52	0.82	0.45	0.70	1.00

Table A-9: Performance Measures Correlation Matrix (2009) - Friday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.51	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.60	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.51	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.51	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.51	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.53	0.98	0.97	0.97	0.97	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.94	0.55	0.97	0.95	0.95	0.95	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.81	0.59	0.89	0.82	0.82	0.82	0.88	0.91	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.37	0.37	0.48	0.38	0.38	0.39	0.58	0.65	0.70	1.00	-	-	-	-	-	-	-	-
TTV_85	0.38	0.34	0.48	0.39	0.39	0.40	0.60	0.66	0.66	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.32	0.44	0.45	0.33	0.33	0.33	0.46	0.53	0.81	0.77	0.68	1.00	-	-	-	-	-	-
BT	0.26	0.34	0.38	0.27	0.27	0.28	0.40	0.47	0.77	0.73	0.64	0.99	1.00	-	-	-	-	-
BTI	-0.07	0.14	0.04	-0.07	-0.07	-0.06	0.09	0.18	0.42	0.66	0.58	0.77	0.79	1.00	-	-	-	-
PTI	-0.09	0.20	0.03	-0.08	-0.08	-0.08	0.09	0.17	0.38	0.69	0.62	0.72	0.73	0.97	1.00	-	-	-
λ Skew	-0.06	0.08	0.01	-0.06	-0.06	-0.06	0.13	0.18	0.21	0.65	0.70	0.41	0.41	0.64	0.72	1.00	-	-
λ Var	-0.15	0.06	-0.06	-0.14	-0.14	-0.14	0.05	0.12	0.18	0.68	0.69	0.44	0.44	0.76	0.85	0.91	1.00	-
TTI	-0.15	0.33	-0.03	-0.14	-0.14	-0.14	0.01	0.08	0.22	0.55	0.53	0.52	0.49	0.75	0.87	0.64	0.80	1.00

Table A-10: Performance Measures Correlation Matrix (2009) - Friday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.44	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.48	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.44	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.45	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.45	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.45	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.46	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.50	0.98	0.98	0.98	0.98	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.56	0.36	0.60	0.56	0.56	0.57	0.67	0.68	0.71	1.00	-	-	-	-	-	-	-	-
TTV_85	0.49	0.28	0.53	0.50	0.50	0.50	0.61	0.62	0.62	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.45	0.46	0.50	0.46	0.46	0.46	0.55	0.57	0.64	0.89	0.80	1.00	-	-	-	-	-	-
BT	0.34	0.31	0.38	0.34	0.35	0.35	0.44	0.46	0.54	0.84	0.75	0.98	1.00	-	-	-	-	-
BTI	-0.21	0.01	-0.17	-0.21	-0.21	-0.21	-0.10	-0.08	-0.01	0.56	0.52	0.69	0.78	1.00	-	-	-	-
PTI	-0.21	0.07	-0.16	-0.20	-0.20	-0.20	-0.09	-0.07	-0.01	0.61	0.61	0.68	0.74	0.96	1.00	-	-	-
λ Skew	-0.08	0.01	-0.05	-0.08	-0.08	-0.09	0.05	0.06	0.07	0.71	0.78	0.59	0.62	0.76	0.83	1.00	-	-
λ Var	-0.18	-0.02	-0.14	-0.18	-0.18	-0.18	-0.05	-0.04	-0.02	0.66	0.72	0.56	0.60	0.83	0.92	0.95	1.00	-
TTI	-0.24	0.15	-0.19	-0.23	-0.23	-0.23	-0.14	-0.13	-0.09	0.43	0.45	0.45	0.44	0.68	0.85	0.62	0.77	1.00

Table A-11: Performance Measures Correlation Matrix (2009) - Friday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.34	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.71	0.78	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.97	0.43	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.94	0.47	0.82	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.76	0.71	0.99	0.84	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.56	0.81	0.98	0.66	0.69	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.51	0.83	0.96	0.61	0.64	0.92	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.46	0.86	0.94	0.56	0.59	0.89	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.24	0.82	0.84	0.34	0.39	0.77	0.93	0.96	0.96	1.00	-	-	-	-	-	-	-	-
TTV_85	0.24	0.81	0.84	0.34	0.38	0.77	0.93	0.95	0.96	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.85	0.83	0.34	0.37	0.76	0.92	0.95	0.97	0.99	0.99	1.00	-	-	-	-	-	-
BT	0.24	0.85	0.82	0.33	0.37	0.74	0.91	0.94	0.97	0.98	0.98	1.00	1.00	-	-	-	-	-
BTI	-0.17	0.43	0.19	-0.12	-0.10	0.09	0.27	0.32	0.39	0.43	0.40	0.48	0.52	1.00	-	-	-	-
PTI	-0.09	0.55	0.38	-0.04	-0.02	0.27	0.49	0.55	0.59	0.66	0.64	0.69	0.71	0.86	1.00	-	-	-
λ Skew	-0.12	0.17	-0.01	-0.11	-0.11	-0.09	0.06	0.08	0.11	0.14	0.13	0.16	0.19	0.58	0.46	1.00	-	-
λ Var	-0.12	0.45	0.25	-0.08	-0.05	0.13	0.36	0.41	0.44	0.51	0.49	0.53	0.55	0.83	0.87	0.73	1.00	-
TTI	-0.06	0.59	0.45	-0.01	0.01	0.34	0.57	0.62	0.65	0.74	0.72	0.75	0.75	0.73	0.97	0.34	0.80	1.00

Table A-12: Performance Measures Correlation Matrix (2009) - Friday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.47	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.49	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.47	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.47	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.47	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.47	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.47	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.48	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.58	0.30	0.61	0.58	0.58	0.59	0.69	0.69	0.69	1.00	-	-	-	-	-	-	-	-
TTV_85	0.43	0.23	0.46	0.43	0.43	0.43	0.55	0.55	0.54	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.62	0.36	0.65	0.62	0.62	0.62	0.70	0.70	0.74	0.90	0.84	1.00	-	-	-	-	-	-
BT	0.54	0.19	0.56	0.54	0.54	0.54	0.62	0.62	0.66	0.87	0.81	0.97	1.00	-	-	-	-	-
BTI	-0.14	-0.02	-0.11	-0.14	-0.14	-0.14	-0.04	-0.04	-0.01	0.55	0.63	0.55	0.62	1.00	-	-	-	-
PTI	-0.17	0.00	-0.14	-0.17	-0.17	-0.17	-0.06	-0.06	-0.04	0.54	0.63	0.50	0.54	0.96	1.00	-	-	-
λ Skew	-0.05	-0.01	-0.02	-0.05	-0.05	-0.05	0.08	0.08	0.07	0.71	0.82	0.52	0.57	0.76	0.76	1.00	-	-
λ Var	-0.15	-0.03	-0.12	-0.16	-0.16	-0.15	-0.03	-0.03	-0.03	0.64	0.76	0.47	0.50	0.88	0.91	0.92	1.00	-
TTI	-0.22	0.02	-0.19	-0.23	-0.23	-0.22	-0.14	-0.14	-0.13	0.35	0.45	0.32	0.30	0.71	0.87	0.51	0.74	1.00

Table A-13: Performance Measures Correlation Matrix (2009) - Saturday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.38	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.38	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.38	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.38	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.38	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.38	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.38	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.58	0.23	0.61	0.58	0.58	0.58	0.69	0.69	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.45	0.19	0.49	0.45	0.45	0.46	0.58	0.58	0.57	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.63	0.25	0.66	0.63	0.63	0.64	0.73	0.73	0.74	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.57	0.14	0.59	0.57	0.57	0.57	0.67	0.67	0.68	0.96	0.93	0.98	1.00	-	-	-	-	-
BTI	-0.21	-0.19	-0.19	-0.21	-0.21	-0.21	-0.09	-0.09	-0.09	0.57	0.65	0.53	0.62	1.00	-	-	-	-
PTI	-0.22	-0.09	-0.18	-0.22	-0.22	-0.21	-0.09	-0.09	-0.09	0.59	0.68	0.53	0.57	0.94	1.00	-	-	-
λ Skew	-0.06	-0.02	-0.03	-0.06	-0.06	-0.06	0.08	0.08	0.07	0.74	0.82	0.66	0.70	0.86	0.88	1.00	-	-
λ Var	-0.16	-0.07	-0.13	-0.16	-0.16	-0.16	-0.03	-0.03	-0.04	0.67	0.76	0.59	0.63	0.92	0.96	0.96	1.00	-
TTI	-0.27	0.01	-0.24	-0.27	-0.27	-0.26	-0.17	-0.18	-0.18	0.36	0.45	0.31	0.28	0.66	0.86	0.60	0.75	1.00

Table A-14: Performance Measures Correlation Matrix (2009) - Saturday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.59	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.58	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.58	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.59	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.59	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	1.00	0.60	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.65	0.99	0.98	0.98	0.98	0.98	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.91	0.65	0.93	0.92	0.92	0.93	0.93	0.94	0.94	1.00	-	-	-	-	-	-	-	-
TTV_85	0.89	0.62	0.91	0.89	0.89	0.90	0.91	0.91	0.91	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.57	0.68	0.62	0.58	0.58	0.58	0.59	0.60	0.73	0.71	0.68	1.00	-	-	-	-	-	-
BT	0.46	0.55	0.50	0.47	0.47	0.47	0.48	0.49	0.63	0.60	0.56	0.98	1.00	-	-	-	-	-
BTI	-0.19	0.13	-0.15	-0.18	-0.18	-0.18	-0.17	-0.16	-0.03	0.01	0.00	0.50	0.58	1.00	-	-	-	-
PTI	-0.20	0.14	-0.17	-0.20	-0.20	-0.19	-0.18	-0.18	-0.07	-0.01	0.00	0.39	0.43	0.90	1.00	-	-	-
λ Skew	-0.07	-0.03	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.04	-0.03	-0.05	0.03	0.06	0.25	0.13	1.00	-	-
λ Var	-0.31	-0.10	-0.29	-0.31	-0.31	-0.30	-0.29	-0.29	-0.27	-0.14	-0.11	-0.06	-0.05	0.66	0.80	0.10	1.00	-
TTI	-0.20	0.11	-0.18	-0.20	-0.20	-0.19	-0.19	-0.18	-0.13	-0.03	0.01	0.16	0.15	0.53	0.84	-0.02	0.74	1.00

Table A-15: Performance Measures Correlation Matrix (2009) - Saturday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.42	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.47	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.42	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.42	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.42	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.43	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.44	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.48	0.99	0.99	0.99	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.84	0.52	0.87	0.85	0.85	0.86	0.87	0.88	0.90	1.00	-	-	-	-	-	-	-	-
TTV_85	0.81	0.47	0.84	0.82	0.82	0.83	0.85	0.85	0.86	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.63	0.61	0.68	0.65	0.65	0.65	0.67	0.68	0.75	0.87	0.79	1.00	-	-	-	-	-	-
BT	0.53	0.37	0.56	0.54	0.54	0.54	0.56	0.58	0.65	0.76	0.67	0.94	1.00	-	-	-	-	-
BTI	-0.20	-0.03	-0.17	-0.19	-0.19	-0.19	-0.17	-0.16	-0.09	0.11	0.06	0.36	0.48	1.00	-	-	-	-
PTI	-0.24	0.12	-0.20	-0.23	-0.23	-0.22	-0.21	-0.20	-0.14	0.08	0.06	0.29	0.31	0.87	1.00	-	-	-
λ Skew	-0.07	0.00	-0.07	-0.07	-0.07	-0.09	-0.07	-0.06	-0.05	0.03	0.01	0.10	0.17	0.37	0.19	1.00	-	-
λ Var	-0.33	-0.03	-0.30	-0.32	-0.32	-0.31	-0.29	-0.29	-0.26	-0.02	0.01	0.06	0.07	0.77	0.90	0.24	1.00	-
TTI	-0.24	0.27	-0.20	-0.23	-0.24	-0.22	-0.21	-0.21	-0.17	0.03	0.06	0.15	0.04	0.45	0.82	-0.03	0.75	1.00

Table A-16: Performance Measures Correlation Matrix (2009) - Saturday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.41	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.40	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.40	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.40	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.40	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.40	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.78	0.37	0.81	0.79	0.80	0.81	0.82	0.83	0.83	1.00	-	-	-	-	-	-	-	-
TTV_85	0.60	0.26	0.63	0.61	0.61	0.63	0.65	0.65	0.65	0.90	1.00	-	-	-	-	-	-	-
TTV_95	0.81	0.36	0.84	0.82	0.82	0.83	0.84	0.85	0.85	0.95	0.89	1.00	-	-	-	-	-	-
BT	0.82	0.23	0.85	0.84	0.84	0.85	0.86	0.86	0.87	0.89	0.77	0.95	1.00	-	-	-	-	-
BTI	-0.20	-0.15	-0.20	-0.20	-0.20	-0.20	-0.19	-0.18	-0.18	0.03	0.07	0.04	0.08	1.00	-	-	-	-
PTI	-0.26	-0.11	-0.26	-0.27	-0.27	-0.26	-0.26	-0.25	-0.25	-0.03	0.06	-0.04	-0.10	0.84	1.00	-	-	-
λ Skew	-0.08	-0.03	-0.09	-0.09	-0.09	-0.10	-0.08	-0.08	-0.08	0.05	0.07	0.01	0.10	0.37	0.11	1.00	-	-
λ Var	-0.31	-0.12	-0.31	-0.32	-0.32	-0.31	-0.30	-0.30	-0.30	0.02	0.10	-0.05	-0.10	0.86	0.94	0.28	1.00	-
TTI	-0.28	-0.07	-0.29	-0.30	-0.30	-0.28	-0.28	-0.28	-0.28	-0.05	0.09	-0.06	-0.20	0.50	0.88	-0.09	0.79	1.00

Table A-17: Performance Measures Correlation Matrix (2009) - Weekday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.93	0.72	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.62	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.62	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.65	0.96	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.77	0.68	0.95	0.77	0.78	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.70	0.67	0.91	0.70	0.71	0.76	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.62	0.67	0.86	0.63	0.63	0.69	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.28	0.49	0.61	0.29	0.29	0.37	0.83	0.88	0.92	1.00	-	-	-	-	-	-	-	-
TTV_85	0.27	0.48	0.61	0.28	0.28	0.37	0.83	0.88	0.91	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.27	0.52	0.61	0.28	0.29	0.36	0.81	0.87	0.92	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.25	0.49	0.58	0.26	0.26	0.34	0.79	0.86	0.91	0.99	0.97	1.00	1.00	-	-	-	-	-
BTI	-0.05	0.28	0.23	-0.04	-0.04	0.03	0.41	0.48	0.58	0.67	0.65	0.73	0.75	1.00	-	-	-	-
PTI	-0.03	0.30	0.26	-0.03	-0.03	0.06	0.45	0.52	0.60	0.72	0.71	0.75	0.76	0.94	1.00	-	-	-
λ Skew	0.03	0.26	0.23	0.03	0.03	0.04	0.39	0.45	0.51	0.59	0.56	0.62	0.64	0.80	0.72	1.00	-	-
λ Var	-0.02	0.30	0.27	-0.02	-0.01	0.05	0.49	0.56	0.62	0.76	0.75	0.78	0.79	0.93	0.95	0.86	1.00	-
TTI	-0.07	0.29	0.22	-0.06	-0.06	0.04	0.41	0.47	0.54	0.67	0.67	0.69	0.68	0.84	0.96	0.55	0.87	1.00

Table A-18: Performance Measures Correlation Matrix (2009) - Weekday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.38	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.39	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.37	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.37	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.38	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.37	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.37	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.39	0.98	0.97	0.97	0.98	0.98	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.64	0.25	0.69	0.66	0.66	0.67	0.74	0.75	0.75	1.00	-	-	-	-	-	-	-	-
TTV_85	0.57	0.22	0.61	0.59	0.59	0.59	0.67	0.68	0.68	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.44	0.25	0.50	0.46	0.46	0.46	0.51	0.52	0.64	0.73	0.68	1.00	-	-	-	-	-	-
BT	0.32	0.14	0.37	0.34	0.34	0.34	0.39	0.40	0.54	0.64	0.60	0.67	1.00	-	-	-	-	-
BTI	-0.21	-0.09	-0.17	-0.20	-0.20	-0.20	-0.15	-0.14	-0.01	0.25	0.26	0.98	0.76	1.00	-	-	-	-
PTI	-0.22	-0.06	-0.18	-0.22	-0.22	-0.22	-0.15	-0.15	-0.03	0.29	0.32	0.62	0.69	0.96	1.00	-	-	-
λ Skew	-0.08	-0.05	-0.06	-0.08	-0.08	-0.09	0.02	0.02	0.03	0.59	0.70	0.39	0.40	0.49	0.57	1.00	-	-
λ Var	-0.23	-0.12	-0.21	-0.24	-0.24	-0.23	-0.14	-0.14	-0.12	0.45	0.53	0.31	0.33	0.64	0.75	0.88	1.00	-
TTI	-0.27	-0.01	-0.25	-0.28	-0.28	-0.27	-0.22	-0.22	-0.16	0.17	0.22	0.30	0.32	0.63	0.81	0.45	0.75	1.00

Table A-19: Performance Measures Correlation Matrix (2009) - Weekday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.81	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.59	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.62	0.87	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.87	0.75	0.98	0.90	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.65	0.82	0.97	0.69	0.73	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.60	0.82	0.94	0.64	0.68	0.86	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.54	0.82	0.91	0.58	0.62	0.81	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.31	0.76	0.80	0.36	0.41	0.67	0.92	0.95	0.96	1.00	-	-	-	-	-	-	-	-
TTV_85	0.32	0.75	0.80	0.36	0.41	0.67	0.92	0.94	0.95	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.31	0.76	0.78	0.36	0.40	0.64	0.90	0.94	0.97	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.30	0.74	0.76	0.34	0.38	0.60	0.87	0.92	0.96	0.97	0.96	1.00	1.00	-	-	-	-	-
BTI	-0.19	0.27	0.11	-0.16	-0.15	-0.04	0.21	0.28	0.38	0.41	0.36	0.49	0.52	1.00	-	-	-	-
PTI	-0.15	0.35	0.20	-0.13	-0.11	0.06	0.32	0.39	0.47	0.53	0.50	0.58	0.61	0.93	1.00	-	-	-
λ Skew	-0.09	0.15	0.04	-0.09	-0.09	-0.07	0.11	0.18	0.24	0.25	0.20	0.31	0.36	0.72	0.62	1.00	-	-
λ Var	-0.14	0.32	0.18	-0.11	-0.10	0.03	0.30	0.37	0.44	0.50	0.46	0.55	0.58	0.92	0.94	0.78	1.00	-
TTI	-0.15	0.39	0.25	-0.12	-0.10	0.11	0.38	0.44	0.50	0.58	0.57	0.62	0.63	0.82	0.96	0.47	0.86	1.00

Table A-20: Performance Measures Correlation Matrix (2009) - Weekday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.53	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.53	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.53	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.53	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.54	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.54	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.53	0.99	0.99	0.98	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.60	0.39	0.65	0.61	0.61	0.62	0.70	0.71	0.72	1.00	-	-	-	-	-	-	-	-
TTV_85	0.49	0.34	0.54	0.50	0.50	0.51	0.60	0.61	0.61	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.64	0.39	0.68	0.65	0.65	0.66	0.72	0.73	0.77	0.89	0.82	1.00	-	-	-	-	-	-
BT	0.59	0.28	0.62	0.60	0.60	0.60	0.66	0.67	0.72	0.84	0.77	0.98	1.00	-	-	-	-	-
BTI	-0.13	-0.09	-0.10	-0.12	-0.12	-0.12	-0.04	-0.03	0.00	0.49	0.54	0.44	0.49	1.00	-	-	-	-
PTI	-0.21	-0.07	-0.18	-0.21	-0.21	-0.20	-0.13	-0.12	-0.11	0.39	0.46	0.31	0.32	0.90	1.00	-	-	-
λ Skew	-0.04	-0.02	-0.01	-0.04	-0.04	-0.04	0.06	0.07	0.06	0.59	0.69	0.41	0.43	0.70	0.66	1.00	-	-
λ Var	-0.22	-0.07	-0.18	-0.21	-0.21	-0.21	-0.11	-0.11	-0.11	0.48	0.58	0.31	0.31	0.88	0.94	0.82	1.00	-
TTI	-0.29	-0.03	-0.26	-0.29	-0.29	-0.28	-0.24	-0.23	-0.22	0.16	0.22	0.09	0.05	0.57	0.86	0.35	0.74	1.00

Table A-21: Performance Measures Correlation Matrix (2009) - Weekend (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.34	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.35	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.34	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.34	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.34	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.34	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	1.00	0.34	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	1.00	0.34	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.91	0.32	0.92	0.91	0.91	0.92	0.93	0.93	0.93	1.00	-	-	-	-	-	-	-	-
TTV_85	0.86	0.29	0.87	0.86	0.86	0.87	0.88	0.88	0.88	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.91	0.32	0.93	0.92	0.92	0.92	0.93	0.93	0.93	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.90	0.22	0.91	0.91	0.91	0.91	0.91	0.91	0.92	0.92	0.88	0.96	1.00	-	-	-	-	-
BTI	-0.37	-0.29	-0.37	-0.37	-0.37	-0.37	-0.36	-0.36	-0.35	-0.24	-0.22	-0.22	-0.14	1.00	-	-	-	-
PTI	-0.35	-0.16	-0.34	-0.35	-0.35	-0.34	-0.34	-0.34	-0.34	-0.20	-0.15	-0.21	-0.24	0.73	1.00	-	-	-
λ Skew	-0.19	-0.07	-0.19	-0.19	-0.19	-0.20	-0.19	-0.18	-0.18	-0.16	-0.17	-0.17	-0.07	0.49	0.14	1.00	-	-
λ Var	-0.37	-0.17	-0.36	-0.37	-0.37	-0.36	-0.35	-0.35	-0.36	-0.17	-0.12	-0.22	-0.25	0.81	0.92	0.26	1.00	-
TTI	-0.27	-0.04	-0.26	-0.27	-0.27	-0.26	-0.26	-0.26	-0.26	-0.13	-0.08	-0.15	-0.25	0.38	0.91	-0.11	0.76	1.00

Table A-22: Performance Measures Correlation Matrix (2009) - Weekend (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.53	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.53	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.53	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.53	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.53	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	1.00	0.53	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	1.00	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.92	0.54	0.93	0.92	0.92	0.93	0.94	0.94	0.94	1.00	-	-	-	-	-	-	-	-
TTV_85	0.88	0.54	0.90	0.88	0.88	0.90	0.90	0.90	0.90	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.84	0.65	0.86	0.85	0.85	0.85	0.86	0.86	0.88	0.92	0.90	1.00	-	-	-	-	-	-
BT	0.78	0.52	0.79	0.79	0.79	0.79	0.80	0.80	0.83	0.85	0.81	0.96	1.00	-	-	-	-	-
BTI	-0.35	-0.10	-0.34	-0.35	-0.35	-0.35	-0.33	-0.33	-0.31	-0.18	-0.16	-0.02	0.07	1.00	-	-	-	-
PTI	-0.32	-0.03	-0.31	-0.32	-0.32	-0.31	-0.31	-0.31	-0.29	-0.15	-0.12	-0.05	-0.04	0.77	1.00	-	-	-
λ Skew	-0.08	-0.05	-0.07	-0.07	-0.07	-0.08	-0.07	-0.07	-0.06	-0.08	-0.12	0.01	0.08	0.33	0.12	1.00	-	-
λ Var	-0.35	-0.14	-0.34	-0.35	-0.35	-0.34	-0.33	-0.33	-0.33	-0.15	-0.10	-0.16	-0.17	0.79	0.88	0.09	1.00	-
TTI	-0.23	0.02	-0.22	-0.24	-0.24	-0.22	-0.22	-0.22	-0.22	-0.10	-0.05	-0.06	-0.12	0.42	0.90	-0.05	0.71	1.00

Table A-23: Performance Measures Correlation Matrix (2009) - Weekend (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.45	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.53	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.45	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.45	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.46	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.47	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.48	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.89	0.54	0.94	0.91	0.91	0.92	0.94	0.95	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.63	0.49	0.70	0.64	0.64	0.65	0.69	0.73	0.87	1.00	-	-	-	-	-	-	-	-
TTV_85	0.70	0.54	0.77	0.72	0.72	0.73	0.77	0.80	0.90	0.95	1.00	-	-	-	-	-	-	-
TTV_95	0.29	0.43	0.37	0.29	0.29	0.30	0.35	0.40	0.66	0.86	0.78	1.00	-	-	-	-	-	-
BT	0.17	0.25	0.24	0.17	0.17	0.18	0.24	0.29	0.56	0.79	0.68	0.98	1.00	-	-	-	-	-
BTI	-0.10	0.14	-0.03	-0.10	-0.10	-0.09	-0.04	0.01	0.27	0.54	0.43	0.82	0.87	1.00	-	-	-	-
PTI	-0.12	0.22	-0.05	-0.12	-0.12	-0.11	-0.06	-0.02	0.24	0.51	0.42	0.79	0.81	0.96	1.00	-	-	-
λ Skew	-0.11	0.07	-0.08	-0.12	-0.12	-0.13	-0.09	-0.06	0.08	0.29	0.19	0.41	0.43	0.57	0.50	1.00	-	-
λ Var	-0.26	0.06	-0.20	-0.25	-0.25	-0.24	-0.20	-0.16	0.02	0.34	0.24	0.50	0.52	0.79	0.84	0.53	1.00	-
TTI	-0.21	0.32	-0.13	-0.21	-0.21	-0.19	-0.16	-0.14	0.04	0.27	0.23	0.46	0.43	0.60	0.78	0.24	0.78	1.00

Table A-24: Performance Measures Correlation Matrix (2009) - Weekend (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.28	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.34	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.28	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.28	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.28	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.28	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.28	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.29	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.72	0.28	0.75	0.73	0.73	0.74	0.76	0.78	0.78	1.00	-	-	-	-	-	-	-	-
TTV_85	0.68	0.30	0.72	0.69	0.69	0.71	0.73	0.73	0.73	0.89	1.00	-	-	-	-	-	-	-
TTV_95	0.78	0.32	0.81	0.78	0.78	0.80	0.81	0.83	0.83	0.97	0.88	1.00	-	-	-	-	-	-
BT	0.63	-0.28	0.61	0.63	0.63	0.64	0.65	0.66	0.67	0.76	0.60	0.77	1.00	-	-	-	-	-
BTI	-0.22	-0.34	-0.24	-0.22	-0.22	-0.22	-0.21	-0.20	-0.20	0.03	-0.03	0.02	0.28	1.00	-	-	-	-
PTI	-0.26	-0.05	-0.26	-0.27	-0.27	-0.26	-0.26	-0.25	-0.25	-0.01	0.00	-0.03	-0.03	0.80	1.00	-	-	-
λ Skew	-0.06	-0.04	-0.08	-0.07	-0.07	-0.08	-0.07	-0.06	-0.06	0.05	-0.01	0.02	0.10	0.37	0.19	1.00	-	-
λ Var	-0.31	-0.06	-0.31	-0.32	-0.32	-0.31	-0.30	-0.29	-0.29	0.07	0.07	0.00	0.00	0.80	0.93	0.37	1.00	-
TTI	-0.24	0.25	-0.21	-0.25	-0.25	-0.24	-0.23	-0.23	-0.23	-0.01	0.05	-0.03	-0.30	0.28	0.79	-0.01	0.71	1.00

Table A-25: Performance Measures Correlation Matrix (2009) - All (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.60	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.69	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.61	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.61	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.61	0.96	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.83	0.67	0.95	0.83	0.83	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.75	0.66	0.90	0.75	0.75	0.76	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.65	0.65	0.84	0.66	0.66	0.67	0.95	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.28	0.46	0.54	0.29	0.29	0.30	0.77	0.85	0.90	1.00	-	-	-	-	-	-	-	-
TTV_85	0.28	0.46	0.54	0.29	0.29	0.30	0.77	0.85	0.89	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.27	0.48	0.53	0.28	0.28	0.29	0.75	0.83	0.91	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.24	0.45	0.50	0.25	0.25	0.26	0.72	0.82	0.89	0.98	0.96	1.00	1.00	-	-	-	-	-
BTI	-0.04	0.25	0.18	-0.04	-0.04	-0.03	0.36	0.46	0.57	0.69	0.66	0.75	0.76	1.00	-	-	-	-
PTI	-0.05	0.25	0.17	-0.04	-0.04	-0.03	0.36	0.46	0.55	0.70	0.68	0.73	0.74	0.96	1.00	-	-	-
λ Skew	0.04	0.29	0.26	0.04	0.04	0.04	0.47	0.56	0.64	0.79	0.77	0.80	0.81	0.86	0.85	1.00	-	-
λ Var	-0.04	0.25	0.20	-0.03	-0.03	-0.02	0.41	0.50	0.58	0.76	0.75	0.77	0.77	0.93	0.98	0.91	1.00	-
TTI	-0.10	0.23	0.11	-0.10	-0.09	-0.08	0.30	0.38	0.47	0.63	0.63	0.65	0.65	0.88	0.95	0.74	0.93	1.00

Table A-26: Performance Measures Correlation Matrix (2009) - All (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.44	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.46	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.44	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.44	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.44	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.44	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.44	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.44	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.66	0.29	0.70	0.67	0.68	0.68	0.75	0.76	0.76	1.00	-	-	-	-	-	-	-	-
TTV_85	0.56	0.25	0.60	0.58	0.58	0.58	0.66	0.66	0.67	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.63	0.31	0.68	0.65	0.65	0.66	0.72	0.73	0.75	0.96	0.92	1.00	-	-	-	-	-	-
BT	0.53	0.16	0.57	0.55	0.55	0.55	0.62	0.63	0.65	0.93	0.89	0.96	1.00	-	-	-	-	-
BTI	-0.29	-0.22	-0.26	-0.29	-0.28	-0.29	-0.20	-0.20	-0.18	0.37	0.43	0.41	0.53	1.00	-	-	-	-
PTI	-0.26	-0.13	-0.24	-0.27	-0.27	-0.26	-0.18	-0.18	-0.16	0.40	0.47	0.41	0.48	0.92	1.00	-	-	-
λ Skew	-0.07	-0.05	-0.05	-0.07	-0.07	-0.07	0.03	0.03	0.04	0.63	0.72	0.56	0.64	0.78	0.79	1.00	-	-
λ Var	-0.22	-0.13	-0.20	-0.23	-0.23	-0.23	-0.13	-0.13	-0.12	0.49	0.59	0.42	0.50	0.89	0.94	0.90	1.00	-
TTI	-0.26	-0.04	-0.24	-0.27	-0.27	-0.26	-0.21	-0.21	-0.20	0.19	0.25	0.20	0.20	0.62	0.86	0.46	0.72	1.00

Table A-27: Performance Measures Correlation Matrix (2009) - All (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.56	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.85	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.58	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.58	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.92	0.67	0.95	0.94	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.68	0.80	0.95	0.71	0.71	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.63	0.81	0.93	0.66	0.66	0.78	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.55	0.81	0.88	0.58	0.58	0.70	0.96	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.31	0.73	0.73	0.33	0.34	0.51	0.89	0.93	0.95	1.00	-	-	-	-	-	-	-	-
TTV_85	0.30	0.71	0.72	0.32	0.32	0.52	0.89	0.91	0.93	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.30	0.74	0.72	0.32	0.33	0.49	0.87	0.92	0.96	0.99	0.96	1.00	-	-	-	-	-	-
BT	0.29	0.72	0.70	0.31	0.31	0.45	0.85	0.90	0.95	0.98	0.94	1.00	1.00	-	-	-	-	-
BTI	-0.14	0.32	0.13	-0.13	-0.13	-0.06	0.24	0.32	0.43	0.47	0.40	0.55	0.58	1.00	-	-	-	-
PTI	-0.11	0.39	0.23	-0.10	-0.10	0.04	0.37	0.44	0.54	0.60	0.57	0.66	0.67	0.93	1.00	-	-	-
λ Skew	-0.04	0.30	0.15	-0.04	-0.04	-0.03	0.25	0.32	0.41	0.43	0.36	0.49	0.53	0.81	0.72	1.00	-	-
λ Var	-0.09	0.38	0.23	-0.08	-0.08	0.00	0.38	0.45	0.54	0.60	0.56	0.65	0.68	0.91	0.95	0.83	1.00	-
TTI	-0.13	0.40	0.25	-0.11	-0.11	0.08	0.42	0.47	0.54	0.64	0.63	0.67	0.66	0.81	0.95	0.57	0.87	1.00

Table A-28: Performance Measures Correlation Matrix (2009) - All (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.50	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.53	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.51	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.51	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.51	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.51	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.51	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.51	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.59	0.37	0.64	0.60	0.61	0.62	0.69	0.70	0.70	1.00	-	-	-	-	-	-	-	-
TTV_85	0.50	0.32	0.54	0.51	0.51	0.52	0.60	0.61	0.61	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.66	0.41	0.70	0.67	0.67	0.68	0.74	0.75	0.77	0.96	0.91	1.00	-	-	-	-	-	-
BT	0.60	0.25	0.63	0.61	0.61	0.62	0.68	0.69	0.71	0.92	0.89	0.97	1.00	-	-	-	-	-
BTI	-0.17	-0.13	-0.15	-0.18	-0.18	-0.17	-0.09	-0.08	-0.07	0.45	0.53	0.41	0.49	1.00	-	-	-	-
PTI	-0.22	-0.08	-0.20	-0.23	-0.23	-0.22	-0.15	-0.14	-0.14	0.38	0.48	0.32	0.36	0.92	1.00	-	-	-
λ Skew	-0.04	-0.03	-0.03	-0.05	-0.05	-0.05	0.05	0.05	0.05	0.57	0.72	0.47	0.53	0.69	0.65	1.00	-	-
λ Var	-0.22	-0.08	-0.19	-0.22	-0.22	-0.21	-0.12	-0.12	-0.12	0.49	0.59	0.38	0.42	0.90	0.94	0.81	1.00	-
TTI	-0.28	-0.01	-0.26	-0.29	-0.29	-0.28	-0.24	-0.23	-0.23	0.17	0.23	0.12	0.08	0.60	0.86	0.35	0.73	1.00

Table A-29: Performance Measures Correlation Matrix (2010) - Monday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.57	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.90	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.59	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.59	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.94	0.70	0.98	0.94	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.76	0.80	0.95	0.77	0.77	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.72	0.83	0.94	0.73	0.74	0.87	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.63	0.86	0.87	0.64	0.64	0.76	0.89	0.93	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.26	0.73	0.64	0.28	0.28	0.52	0.82	0.86	0.83	1.00	-	-	-	-	-	-	-	-
TTV_85	0.21	0.67	0.59	0.23	0.24	0.50	0.80	0.83	0.76	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.35	0.80	0.67	0.36	0.36	0.53	0.76	0.83	0.95	0.89	0.82	1.00	-	-	-	-	-	-
BT	0.35	0.79	0.65	0.36	0.36	0.50	0.72	0.79	0.94	0.84	0.75	0.99	1.00	-	-	-	-	-
BTI	0.07	0.61	0.37	0.09	0.09	0.22	0.49	0.56	0.67	0.73	0.66	0.78	0.78	1.00	-	-	-	-
PTI	0.02	0.56	0.36	0.04	0.04	0.25	0.52	0.57	0.61	0.78	0.76	0.73	0.69	0.91	1.00	-	-	-
λ Skew	0.04	0.32	0.14	0.05	0.04	0.03	0.20	0.27	0.34	0.34	0.27	0.39	0.42	0.76	0.57	1.00	-	-
λ Var	-0.04	0.48	0.26	-0.02	-0.02	0.14	0.44	0.49	0.50	0.71	0.69	0.62	0.59	0.92	0.93	0.75	1.00	-
TTI	-0.05	0.42	0.28	-0.03	-0.03	0.23	0.44	0.47	0.44	0.68	0.71	0.55	0.49	0.67	0.89	0.28	0.74	1.00

Table A-30: Performance Measures Correlation Matrix (2010) - Monday (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.64	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.66	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.64	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.64	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.64	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.64	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.64	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.64	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.38	0.28	0.48	0.38	0.38	0.52	0.54	0.54	0.54	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.22	0.40	0.30	0.29	0.44	0.46	0.46	0.46	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.41	0.31	0.51	0.42	0.42	0.55	0.57	0.57	0.57	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.53	0.24	0.60	0.53	0.53	0.64	0.66	0.66	0.66	0.92	0.89	0.94	1.00	-	-	-	-	-
BTI	-0.31	-0.29	-0.24	-0.31	-0.31	-0.22	-0.19	-0.19	-0.18	0.48	0.52	0.49	0.49	1.00	-	-	-	-
PTI	-0.16	-0.07	-0.05	-0.16	-0.16	-0.01	0.02	0.02	0.01	0.82	0.87	0.80	0.66	0.75	1.00	-	-	-
λ Skew	-0.15	-0.08	-0.15	-0.14	-0.15	-0.17	-0.15	-0.15	-0.14	-0.09	-0.08	-0.05	0.04	0.44	0.04	1.00	-	-
λ Var	-0.26	-0.15	-0.17	-0.26	-0.26	-0.13	-0.10	-0.11	-0.11	0.66	0.70	0.63	0.54	0.90	0.88	0.25	1.00	-
TTI	-0.13	-0.01	-0.01	-0.12	-0.13	0.03	0.05	0.05	0.04	0.83	0.88	0.81	0.64	0.64	0.99	-0.06	0.82	1.00

Table A-31: Performance Measures Correlation Matrix (2010) - Monday (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.50	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.89	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.52	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.54	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.90	0.64	0.99	0.91	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.76	0.74	0.97	0.78	0.81	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.72	0.76	0.95	0.74	0.77	0.91	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.65	0.81	0.90	0.68	0.70	0.84	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.23	0.68	0.64	0.26	0.30	0.57	0.80	0.84	0.86	1.00	-	-	-	-	-	-	-	-
TTV_85	0.22	0.65	0.63	0.25	0.29	0.57	0.80	0.83	0.84	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.23	0.73	0.61	0.26	0.29	0.52	0.76	0.82	0.89	0.96	0.94	1.00	-	-	-	-	-	-
BT	0.22	0.73	0.57	0.25	0.28	0.46	0.71	0.78	0.87	0.91	0.87	0.99	1.00	-	-	-	-	-
BTI	-0.13	0.45	0.10	-0.11	-0.09	0.00	0.21	0.28	0.41	0.49	0.43	0.61	0.67	1.00	-	-	-	-
PTI	-0.11	0.45	0.20	-0.09	-0.07	0.12	0.34	0.40	0.49	0.64	0.62	0.70	0.70	0.90	1.00	-	-	-
λ Skew	-0.05	0.28	0.05	-0.04	-0.04	-0.05	0.13	0.19	0.27	0.31	0.25	0.38	0.45	0.72	0.63	1.00	-	-
λ Var	-0.11	0.40	0.16	-0.09	-0.07	0.06	0.30	0.36	0.44	0.60	0.56	0.64	0.66	0.87	0.91	0.80	1.00	-
TTI	-0.12	0.34	0.21	-0.09	-0.07	0.19	0.35	0.37	0.41	0.61	0.64	0.59	0.53	0.59	0.87	0.31	0.70	1.00

Table A-32: Performance Measures Correlation Matrix (2010) - Monday (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.25	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.27	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.24	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.24	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.25	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.25	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.25	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.25	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.34	0.13	0.44	0.34	0.34	0.46	0.51	0.51	0.51	1.00	-	-	-	-	-	-	-	-
TTV_85	0.24	0.11	0.34	0.24	0.24	0.37	0.42	0.42	0.41	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.37	0.14	0.46	0.37	0.36	0.48	0.53	0.53	0.53	0.98	0.97	1.00	-	-	-	-	-	-
BT	0.43	-0.03	0.51	0.43	0.43	0.52	0.57	0.58	0.58	0.90	0.87	0.94	1.00	-	-	-	-	-
BTI	-0.23	-0.20	-0.16	-0.23	-0.23	-0.14	-0.10	-0.10	-0.09	0.57	0.60	0.60	0.63	1.00	-	-	-	-
PTI	-0.15	-0.02	-0.04	-0.15	-0.15	-0.01	0.03	0.03	0.03	0.81	0.85	0.80	0.65	0.77	1.00	-	-	-
λ Skew	-0.07	-0.03	-0.07	-0.07	-0.07	-0.08	-0.05	-0.05	-0.05	0.07	0.08	0.09	0.19	0.39	0.08	1.00	-	-
λ Var	-0.20	-0.03	-0.11	-0.20	-0.20	-0.09	-0.04	-0.04	-0.04	0.75	0.79	0.72	0.63	0.88	0.90	0.28	1.00	-
TTI	-0.12	0.05	-0.02	-0.12	-0.12	0.01	0.05	0.05	0.05	0.81	0.85	0.79	0.60	0.65	0.98	-0.01	0.85	1.00

Table A-33: Performance Measures Correlation Matrix (2010) - Wednesday (8 AM - 9 AM)

MOE	MinTravel_ Time	MaxTravel Time	AvgTravel _Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.65	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.42	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.43	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.93	0.57	0.99	0.94	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.78	0.73	0.97	0.79	0.80	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.74	0.76	0.95	0.76	0.77	0.90	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.66	0.81	0.90	0.68	0.69	0.84	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.22	0.76	0.60	0.24	0.26	0.51	0.78	0.82	0.87	1.00	-	-	-	-	-	-	-	-
TTV_85	0.21	0.72	0.59	0.23	0.24	0.51	0.78	0.81	0.85	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.21	0.79	0.58	0.24	0.25	0.48	0.76	0.81	0.87	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.21	0.79	0.56	0.23	0.24	0.45	0.74	0.79	0.86	0.97	0.94	0.99	1.00	-	-	-	-	-
BTI	-0.07	0.58	0.19	-0.05	-0.04	0.08	0.34	0.41	0.50	0.65	0.59	0.70	0.74	1.00	-	-	-	-
PTI	-0.07	0.56	0.26	-0.04	-0.04	0.18	0.43	0.48	0.55	0.76	0.73	0.77	0.76	0.89	1.00	-	-	-
λ Skew	-0.03	0.40	0.07	-0.02	-0.02	-0.03	0.15	0.22	0.30	0.34	0.27	0.42	0.50	0.78	0.53	1.00	-	-
λ Var	-0.07	0.54	0.21	-0.05	-0.04	0.11	0.37	0.43	0.51	0.69	0.65	0.72	0.74	0.95	0.94	0.69	1.00	-
TTI	-0.09	0.43	0.23	-0.07	-0.06	0.20	0.38	0.42	0.46	0.68	0.68	0.65	0.61	0.64	0.91	0.25	0.74	1.00

Table A-34: Performance Measures Correlation Matrix (2010) - Wednesday (12 PM - 1 PM)

MOE	MinTravel_ Time	MaxTravel _Time	AvgTravel _Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.57	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.55	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.55	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.55	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.55	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.55	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.55	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.39	0.25	0.50	0.40	0.40	0.54	0.55	0.55	0.56	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.20	0.40	0.29	0.29	0.44	0.46	0.45	0.46	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.40	0.28	0.50	0.40	0.40	0.54	0.56	0.55	0.56	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.53	0.20	0.61	0.53	0.53	0.65	0.66	0.66	0.67	0.94	0.91	0.96	1.00	-	-	-	-	-
BTI	-0.30	-0.25	-0.22	-0.29	-0.29	-0.18	-0.16	-0.16	-0.15	0.54	0.58	0.56	0.53	1.00	-	-	-	-
PTI	-0.15	-0.03	-0.04	-0.15	-0.15	0.01	0.02	0.02	0.03	0.80	0.85	0.82	0.70	0.81	1.00	-	-	-
λ Skew	-0.11	-0.07	-0.12	-0.11	-0.11	-0.14	-0.12	-0.12	-0.12	-0.09	-0.08	-0.10	-0.05	0.27	-0.03	1.00	-	-
λ Var	-0.25	-0.11	-0.16	-0.25	-0.25	-0.12	-0.10	-0.10	-0.10	0.65	0.69	0.64	0.55	0.91	0.85	0.26	1.00	-
TTI	-0.12	0.02	-0.01	-0.12	-0.12	0.04	0.05	0.05	0.06	0.82	0.87	0.84	0.70	0.74	0.99	-0.09	0.81	1.00

Table A-35: Performance Measures Correlation Matrix (2010) - Wednesday (5 PM - 6 PM)

MOE	MinTravel_ Time	MaxTravel _Time	AvgTravel _Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.36	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.81	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.95	0.46	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.93	0.47	0.95	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.83	0.55	0.99	0.95	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.70	0.64	0.98	0.86	0.87	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.69	0.66	0.97	0.83	0.85	0.94	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.58	0.69	0.91	0.73	0.75	0.87	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.24	0.65	0.71	0.43	0.47	0.66	0.83	0.86	0.91	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.63	0.71	0.43	0.46	0.66	0.83	0.85	0.89	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.66	0.67	0.40	0.42	0.60	0.78	0.82	0.92	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.24	0.64	0.64	0.38	0.40	0.57	0.75	0.80	0.90	0.95	0.91	1.00	1.00	-	-	-	-	-
BTI	-0.15	0.40	0.12	-0.09	-0.07	0.05	0.23	0.28	0.37	0.53	0.49	0.55	0.55	1.00	-	-	-	-
PTI	-0.15	0.41	0.16	-0.08	-0.07	0.10	0.28	0.32	0.40	0.59	0.58	0.59	0.57	0.89	1.00	-	-	-
λ Skew	-0.09	0.17	-0.03	-0.09	-0.09	-0.09	0.02	0.06	0.09	0.18	0.14	0.18	0.21	0.67	0.45	1.00	-	-
λ Var	-0.16	0.41	0.12	-0.09	-0.08	0.06	0.24	0.29	0.35	0.55	0.53	0.52	0.51	0.93	0.91	0.65	1.00	-
TTI	-0.15	0.34	0.12	-0.10	-0.09	0.11	0.22	0.25	0.29	0.49	0.51	0.45	0.40	0.62	0.89	0.20	0.71	1.00

Table A-36: Performance Measures Correlation Matrix (2010) - Wednesday (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.65	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.67	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.66	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.66	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.66	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.66	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.66	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.66	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.36	0.31	0.46	0.36	0.36	0.47	0.52	0.52	0.52	1.00	-	-	-	-	-	-	-	-
TTV_85	0.26	0.23	0.36	0.25	0.25	0.37	0.42	0.42	0.42	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.37	0.34	0.47	0.37	0.37	0.48	0.52	0.53	0.53	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.47	0.32	0.54	0.47	0.47	0.55	0.59	0.60	0.61	0.90	0.83	0.93	1.00	-	-	-	-	-
BTI	-0.23	-0.18	-0.16	-0.23	-0.23	-0.15	-0.11	-0.11	-0.10	0.52	0.55	0.57	0.59	1.00	-	-	-	-
PTI	-0.15	-0.05	-0.04	-0.15	-0.15	-0.02	0.02	0.02	0.02	0.79	0.86	0.80	0.62	0.74	1.00	-	-	-
λ Skew	-0.09	-0.04	-0.09	-0.09	-0.10	-0.11	-0.08	-0.07	-0.07	0.08	0.07	0.09	0.21	0.49	0.10	1.00	-	-
λ Var	-0.20	-0.09	-0.12	-0.21	-0.21	-0.10	-0.05	-0.05	-0.05	0.72	0.77	0.70	0.59	0.85	0.89	0.34	1.00	-
TTI	-0.13	-0.01	-0.02	-0.13	-0.13	0.01	0.04	0.04	0.04	0.79	0.87	0.79	0.57	0.61	0.98	0.00	0.84	1.00

Table A-37: Performance Measures Correlation Matrix (2010) - Friday (8 AM - 9 AM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.50	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.51	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.51	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.51	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.93	0.65	0.98	0.94	0.94	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.90	0.71	0.97	0.90	0.91	0.92	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.83	0.78	0.91	0.83	0.83	0.85	0.95	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.28	0.71	0.46	0.29	0.29	0.36	0.59	0.67	0.75	1.00	-	-	-	-	-	-	-	-
TTV_85	0.26	0.63	0.44	0.27	0.27	0.36	0.59	0.64	0.69	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.25	0.75	0.42	0.26	0.26	0.31	0.53	0.63	0.75	0.96	0.88	1.00	-	-	-	-	-	-
BT	0.22	0.73	0.38	0.23	0.23	0.25	0.48	0.59	0.72	0.93	0.81	0.99	1.00	-	-	-	-	-
BTI	-0.08	0.46	0.06	-0.08	-0.07	-0.04	0.16	0.26	0.41	0.73	0.63	0.80	0.82	1.00	-	-	-	-
PTI	-0.10	0.37	0.07	-0.10	-0.10	0.00	0.19	0.26	0.36	0.76	0.74	0.75	0.71	0.87	1.00	-	-	-
λ Skew	0.02	0.54	0.14	0.02	0.02	0.01	0.24	0.34	0.47	0.72	0.61	0.79	0.83	0.86	0.64	1.00	-	-
λ Var	-0.08	0.43	0.08	-0.07	-0.07	-0.02	0.22	0.30	0.41	0.81	0.78	0.79	0.78	0.91	0.91	0.80	1.00	-
TTI	-0.12	0.20	0.04	-0.11	-0.11	0.04	0.14	0.18	0.22	0.60	0.66	0.52	0.42	0.53	0.87	0.29	0.65	1.00

Table A-38: Performance Measures Correlation Matrix (2010) - Friday (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.59	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.59	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.59	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.59	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.59	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.59	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.60	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.40	0.29	0.50	0.40	0.40	0.54	0.56	0.56	0.56	1.00	-	-	-	-	-	-	-	-
TTV_85	0.32	0.23	0.43	0.32	0.32	0.46	0.49	0.49	0.48	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.42	0.34	0.53	0.43	0.42	0.56	0.58	0.58	0.58	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.56	0.37	0.65	0.56	0.56	0.67	0.69	0.69	0.70	0.94	0.91	0.96	1.00	-	-	-	-	-
BTI	-0.32	-0.18	-0.24	-0.32	-0.32	-0.22	-0.19	-0.19	-0.19	0.48	0.52	0.49	0.44	1.00	-	-	-	-
PTI	-0.16	-0.04	-0.05	-0.16	-0.16	-0.01	0.02	0.01	0.02	0.80	0.84	0.79	0.67	0.78	1.00	-	-	-
λ Skew	-0.09	-0.02	-0.10	-0.08	-0.09	-0.11	-0.09	-0.09	-0.09	-0.06	-0.06	-0.06	0.01	0.41	0.01	1.00	-	-
λ Var	-0.25	-0.12	-0.16	-0.25	-0.25	-0.13	-0.10	-0.10	-0.10	0.65	0.68	0.62	0.53	0.91	0.86	0.35	1.00	-
TTI	-0.13	-0.01	-0.01	-0.12	-0.13	0.03	0.05	0.05	0.05	0.82	0.86	0.81	0.67	0.70	0.99	-0.07	0.82	1.00

Table A-39: Performance Measures Correlation Matrix (2010) - Friday (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.40	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.75	0.75	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.49	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.95	0.53	0.88	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.77	0.69	0.99	0.85	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.60	0.77	0.97	0.69	0.75	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.57	0.79	0.96	0.66	0.72	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.53	0.82	0.94	0.62	0.68	0.90	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.24	0.75	0.80	0.35	0.43	0.76	0.92	0.93	0.94	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.73	0.79	0.33	0.40	0.74	0.91	0.92	0.92	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.79	0.79	0.34	0.41	0.73	0.89	0.92	0.95	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.24	0.80	0.77	0.34	0.40	0.70	0.87	0.90	0.94	0.97	0.95	0.99	1.00	-	-	-	-	-
BTI	-0.14	0.46	0.16	-0.09	-0.06	0.08	0.24	0.29	0.38	0.41	0.38	0.50	0.56	1.00	-	-	-	-
PTI	-0.10	0.54	0.31	-0.05	-0.02	0.24	0.43	0.47	0.53	0.61	0.60	0.67	0.68	0.86	1.00	-	-	-
λ Skew	-0.10	0.24	-0.02	-0.09	-0.09	-0.09	0.02	0.06	0.13	0.12	0.08	0.21	0.27	0.77	0.51	1.00	-	-
λ Var	-0.11	0.54	0.27	-0.05	-0.01	0.19	0.38	0.42	0.48	0.55	0.53	0.61	0.64	0.91	0.93	0.67	1.00	-
TTI	-0.08	0.49	0.34	-0.04	0.00	0.30	0.46	0.48	0.50	0.61	0.63	0.63	0.61	0.60	0.90	0.23	0.76	1.00

Table A-40: Performance Measures Correlation Matrix (2010) - Friday (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.76	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.78	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.77	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.77	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.77	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.77	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.77	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.79	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.39	0.37	0.48	0.38	0.38	0.50	0.54	0.54	0.53	1.00	-	-	-	-	-	-	-	-
TTV_85	0.25	0.26	0.35	0.25	0.24	0.37	0.41	0.41	0.40	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.45	0.50	0.53	0.45	0.44	0.55	0.58	0.59	0.60	0.95	0.91	1.00	-	-	-	-	-	-
BT	0.56	0.58	0.63	0.56	0.56	0.63	0.66	0.67	0.69	0.81	0.74	0.95	1.00	-	-	-	-	-
BTI	-0.25	-0.11	-0.18	-0.25	-0.25	-0.17	-0.14	-0.14	-0.12	0.47	0.52	0.51	0.46	1.00	-	-	-	-
PTI	-0.16	-0.02	-0.05	-0.16	-0.16	-0.03	0.01	0.01	0.01	0.80	0.85	0.72	0.51	0.75	1.00	-	-	-
λ Skew	-0.08	-0.05	-0.09	-0.08	-0.08	-0.10	-0.08	-0.08	-0.07	-0.02	-0.01	0.04	0.13	0.47	0.07	1.00	-	-
λ Var	-0.22	-0.10	-0.13	-0.22	-0.23	-0.11	-0.07	-0.07	-0.08	0.70	0.76	0.61	0.42	0.82	0.92	0.24	1.00	-
TTI	-0.13	0.00	-0.03	-0.13	-0.13	0.01	0.04	0.04	0.03	0.82	0.87	0.71	0.48	0.63	0.98	-0.04	0.88	1.00

Table A-41: Performance Measures Correlation Matrix (2010) - Saturday (8 AM - 9 AM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.88	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.88	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.89	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.89	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.89	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.90	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.42	0.50	0.51	0.41	0.41	0.53	0.57	0.57	0.57	1.00	-	-	-	-	-	-	-	-
TTV_85	0.30	0.41	0.41	0.30	0.30	0.43	0.47	0.46	0.47	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.43	0.54	0.53	0.43	0.43	0.55	0.58	0.58	0.59	0.98	0.97	1.00	-	-	-	-	-	-
BT	0.54	0.62	0.62	0.54	0.54	0.64	0.67	0.67	0.68	0.93	0.90	0.97	1.00	-	-	-	-	-
BTI	-0.26	-0.08	-0.17	-0.25	-0.25	-0.16	-0.12	-0.12	-0.10	0.54	0.58	0.57	0.55	1.00	-	-	-	-
PTI	-0.14	0.04	-0.03	-0.14	-0.14	-0.01	0.03	0.03	0.04	0.79	0.85	0.79	0.66	0.78	1.00	-	-	-
λ Skew	-0.14	-0.08	-0.14	-0.14	-0.14	-0.16	-0.14	-0.12	-0.13	0.01	-0.03	0.00	0.06	0.47	0.08	1.00	-	-
λ Var	-0.20	-0.04	-0.11	-0.21	-0.21	-0.09	-0.06	-0.05	-0.05	0.69	0.73	0.66	0.57	0.89	0.88	0.44	1.00	-
TTI	-0.11	0.06	-0.01	-0.12	-0.12	0.02	0.05	0.05	0.06	0.80	0.87	0.79	0.65	0.70	0.99	0.00	0.84	1.00

Table A-42: Performance Measures Correlation Matrix (2010) - Saturday (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.80	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.81	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.81	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.81	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.81	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.81	1.00	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.82	1.00	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.45	0.43	0.55	0.45	0.45	0.57	0.60	0.60	0.60	1.00	-	-	-	-	-	-	-	-
TTV_85	0.35	0.33	0.44	0.34	0.34	0.46	0.50	0.50	0.50	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.47	0.48	0.56	0.46	0.46	0.57	0.60	0.61	0.62	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.53	0.56	0.61	0.54	0.53	0.62	0.65	0.65	0.68	0.86	0.80	0.95	1.00	-	-	-	-	-
BTI	-0.24	-0.07	-0.16	-0.23	-0.23	-0.14	-0.11	-0.11	-0.08	0.51	0.54	0.58	0.56	1.00	-	-	-	-
PTI	-0.13	-0.03	-0.03	-0.13	-0.13	0.00	0.04	0.04	0.04	0.78	0.83	0.75	0.60	0.77	1.00	-	-	-
λ Skew	-0.10	-0.06	-0.11	-0.11	-0.11	-0.13	-0.11	-0.11	-0.10	-0.05	-0.05	-0.01	0.07	0.40	0.03	1.00	-	-
λ Var	-0.19	-0.09	-0.10	-0.20	-0.20	-0.08	-0.04	-0.04	-0.04	0.70	0.75	0.66	0.51	0.84	0.92	0.23	1.00	-
TTI	-0.10	-0.02	0.00	-0.11	-0.11	0.03	0.06	0.06	0.06	0.79	0.84	0.74	0.57	0.69	0.99	-0.05	0.89	1.00

Table A-43: Performance Measures Correlation Matrix (2010) - Saturday (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.50	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.51	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.51	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.51	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.52	1.00	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.54	1.00	0.98	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.95	0.60	0.98	0.96	0.96	0.97	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.40	0.39	0.50	0.40	0.40	0.50	0.55	0.57	0.60	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.24	0.39	0.29	0.29	0.41	0.46	0.46	0.46	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.35	0.54	0.44	0.35	0.35	0.42	0.46	0.50	0.60	0.86	0.71	1.00	-	-	-	-	-	-
BT	0.31	0.52	0.39	0.32	0.32	0.35	0.39	0.44	0.56	0.72	0.51	0.96	1.00	-	-	-	-	-
BTI	-0.16	0.04	-0.07	-0.09	-0.09	-0.08	-0.07	-0.05	-0.02	0.14	0.11	0.21	0.23	1.00	-	-	-	-
PTI	-0.12	0.11	-0.02	-0.13	-0.13	0.00	0.03	0.05	0.09	0.76	0.82	0.67	0.51	0.22	1.00	-	-	-
λ Skew	-0.10	0.08	-0.09	-0.10	-0.10	-0.11	-0.08	-0.06	-0.02	0.15	0.07	0.20	0.25	0.13	0.18	1.00	-	-
λ Var	-0.17	0.06	-0.09	-0.18	-0.18	-0.08	-0.03	-0.01	0.02	0.70	0.71	0.58	0.48	0.23	0.86	0.47	1.00	-
TTI	-0.08	0.05	0.00	-0.10	-0.10	0.03	0.06	0.06	0.07	0.72	0.83	0.52	0.30	-0.04	0.93	0.03	0.74	1.00

Table A-44: Performance Measures Correlation Matrix (2010) - Saturday (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.39	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.49	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.38	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.38	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.38	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.37	0.99	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.37	0.99	0.98	0.98	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.37	0.99	0.98	0.98	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.19	0.04	0.27	0.18	0.18	0.32	0.35	0.36	0.36	1.00	-	-	-	-	-	-	-	-
TTV_85	0.11	0.04	0.20	0.10	0.10	0.24	0.28	0.28	0.28	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.26	0.10	0.34	0.25	0.25	0.38	0.41	0.42	0.42	0.97	0.96	1.00	-	-	-	-	-	-
BT	-0.04	-0.76	-0.08	-0.04	-0.04	0.04	0.06	0.06	0.07	0.54	0.51	0.54	1.00	-	-	-	-	-
BTI	-0.29	-0.34	-0.25	-0.28	-0.28	-0.19	-0.16	-0.16	-0.15	0.58	0.59	0.59	0.65	1.00	-	-	-	-
PTI	-0.14	-0.03	-0.05	-0.15	-0.15	-0.01	0.02	0.02	0.02	0.88	0.90	0.85	0.46	0.70	1.00	-	-	-
λ Skew	-0.10	0.00	-0.10	-0.10	-0.10	-0.12	-0.09	-0.09	-0.08	0.04	0.03	0.07	0.10	0.49	0.10	1.00	-	-
λ Var	-0.23	-0.06	-0.14	-0.24	-0.24	-0.12	-0.08	-0.08	-0.07	0.81	0.83	0.77	0.46	0.81	0.91	0.32	1.00	-
TTI	-0.09	0.11	0.02	-0.10	-0.10	0.04	0.06	0.07	0.06	0.87	0.89	0.83	0.32	0.52	0.97	-0.01	0.85	1.00

Table A-45: Performance Measures Correlation Matrix (2010) - Weekday (8 AM - 9 AM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.56	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.76	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.58	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.59	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.94	0.70	0.99	0.95	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.77	0.79	0.96	0.78	0.79	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.72	0.80	0.94	0.74	0.74	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.66	0.82	0.90	0.67	0.67	0.82	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.26	0.69	0.63	0.28	0.29	0.52	0.81	0.86	0.89	1.00	-	-	-	-	-	-	-	-
TTV_85	0.25	0.68	0.62	0.27	0.28	0.52	0.81	0.85	0.88	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.27	0.72	0.63	0.28	0.29	0.51	0.81	0.85	0.90	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.25	0.70	0.60	0.27	0.27	0.48	0.78	0.84	0.89	0.98	0.96	1.00	1.00	-	-	-	-	-
BTI	-0.04	0.46	0.23	-0.03	-0.02	0.11	0.37	0.43	0.52	0.63	0.59	0.69	0.72	1.00	-	-	-	-
PTI	-0.02	0.50	0.30	-0.01	0.00	0.21	0.47	0.52	0.59	0.74	0.73	0.76	0.76	0.89	1.00	-	-	-
λ Skew	-0.02	0.26	0.09	-0.01	-0.01	-0.02	0.16	0.22	0.30	0.32	0.26	0.39	0.45	0.80	0.55	1.00	-	-
λ Var	-0.03	0.46	0.26	-0.01	-0.01	0.15	0.43	0.49	0.56	0.70	0.67	0.73	0.75	0.95	0.92	0.75	1.00	-
TTI	-0.03	0.43	0.28	-0.02	-0.01	0.23	0.44	0.47	0.51	0.68	0.69	0.67	0.64	0.69	0.93	0.29	0.76	1.00

Table A-46: Performance Measures Correlation Matrix (2010) - Weekday (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.54	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.64	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.92	0.63	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.92	0.63	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.91	0.62	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.91	0.62	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.91	0.62	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.91	0.62	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.30	0.57	0.49	0.49	0.60	0.62	0.62	0.62	1.00	-	-	-	-	-	-	-	-
TTV_85	0.39	0.25	0.50	0.41	0.41	0.53	0.54	0.54	0.54	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.49	0.34	0.60	0.52	0.52	0.62	0.64	0.64	0.64	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.56	0.26	0.66	0.61	0.61	0.69	0.71	0.71	0.71	0.94	0.91	0.95	1.00	-	-	-	-	-
BTI	-0.31	-0.35	-0.30	-0.35	-0.35	-0.28	-0.26	-0.26	-0.26	0.35	0.38	0.34	0.33	1.00	-	-	-	-
PTI	-0.13	-0.10	-0.07	-0.16	-0.16	-0.04	-0.02	-0.02	-0.01	0.73	0.78	0.72	0.60	0.74	1.00	-	-	-
λ Skew	-0.14	-0.07	-0.14	-0.13	-0.13	-0.15	-0.14	-0.13	-0.14	-0.09	-0.08	-0.10	-0.05	0.39	0.04	1.00	-	-
λ Var	-0.23	-0.21	-0.21	-0.28	-0.28	-0.19	-0.17	-0.17	-0.17	0.51	0.55	0.48	0.40	0.92	0.84	0.37	1.00	-
TTI	-0.08	-0.03	-0.02	-0.11	-0.11	0.02	0.03	0.03	0.04	0.77	0.82	0.75	0.61	0.63	0.99	-0.04	0.77	1.00

Table A-47: Performance Measures Correlation Matrix (2010) - Weekday (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.52	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.84	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.58	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.97	0.60	0.91	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.88	0.69	0.98	0.93	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.70	0.74	0.97	0.76	0.79	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.66	0.73	0.94	0.71	0.73	0.87	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.59	0.73	0.91	0.65	0.67	0.81	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.32	0.64	0.75	0.39	0.42	0.63	0.89	0.92	0.95	1.00	-	-	-	-	-	-	-	-
TTV_85	0.32	0.64	0.75	0.39	0.42	0.64	0.89	0.92	0.94	1.00	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.65	0.74	0.39	0.41	0.61	0.88	0.92	0.95	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.32	0.63	0.72	0.38	0.40	0.58	0.86	0.91	0.95	0.99	0.97	1.00	1.00	-	-	-	-	-
BTI	-0.11	0.37	0.18	-0.07	-0.06	0.05	0.30	0.36	0.42	0.51	0.48	0.54	0.56	1.00	-	-	-	-
PTI	-0.07	0.42	0.26	-0.04	-0.03	0.13	0.41	0.46	0.51	0.63	0.61	0.64	0.64	0.93	1.00	-	-	-
λ Skew	-0.05	0.19	0.07	-0.04	-0.04	-0.04	0.14	0.20	0.25	0.29	0.23	0.32	0.36	0.77	0.65	1.00	-	-
λ Var	-0.08	0.38	0.22	-0.05	-0.04	0.08	0.36	0.42	0.46	0.57	0.55	0.58	0.59	0.91	0.95	0.76	1.00	-
TTI	-0.09	0.39	0.25	-0.05	-0.04	0.16	0.38	0.42	0.45	0.58	0.59	0.57	0.55	0.74	0.92	0.40	0.81	1.00

Table A-48: Performance Measures Correlation Matrix (2010) - Weekday (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.31	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.95	0.32	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.96	0.31	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.96	0.31	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.95	0.31	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.95	0.31	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.95	0.31	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.94	0.31	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.18	0.55	0.48	0.48	0.57	0.60	0.61	0.61	1.00	-	-	-	-	-	-	-	-
TTV_85	0.34	0.15	0.44	0.36	0.36	0.45	0.49	0.49	0.50	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.48	0.20	0.58	0.51	0.51	0.59	0.63	0.63	0.64	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.53	0.14	0.63	0.57	0.57	0.63	0.66	0.67	0.69	0.89	0.82	0.96	1.00	-	-	-	-	-
BTI	-0.23	-0.14	-0.18	-0.23	-0.23	-0.17	-0.14	-0.13	-0.11	0.40	0.44	0.46	0.48	1.00	-	-	-	-
PTI	-0.14	-0.04	-0.06	-0.14	-0.14	-0.04	-0.01	-0.01	0.00	0.72	0.79	0.68	0.53	0.73	1.00	-	-	-
λ Skew	-0.13	-0.03	-0.13	-0.13	-0.13	-0.14	-0.12	-0.12	-0.11	-0.01	-0.03	0.03	0.10	0.40	0.11	1.00	-	-
λ Var	-0.24	-0.07	-0.17	-0.24	-0.24	-0.16	-0.12	-0.12	-0.12	0.57	0.63	0.53	0.42	0.81	0.88	0.31	1.00	-
TTI	-0.11	0.00	-0.02	-0.11	-0.11	0.00	0.03	0.03	0.03	0.74	0.81	0.67	0.48	0.55	0.97	0.00	0.80	1.00

Table A-49: Performance Measures Correlation Matrix (2010) - Weekend (8 AM - 9 AM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.86	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.87	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.86	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.87	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.48	0.53	0.56	0.48	0.48	0.58	0.61	0.61	0.61	1.00	-	-	-	-	-	-	-	-
TTV_85	0.37	0.45	0.46	0.37	0.37	0.47	0.50	0.51	0.51	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.51	0.57	0.58	0.51	0.50	0.60	0.62	0.63	0.63	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.59	0.62	0.66	0.60	0.60	0.67	0.70	0.70	0.71	0.94	0.89	0.97	1.00	-	-	-	-	-
BTI	-0.28	-0.11	-0.19	-0.25	-0.25	-0.18	-0.16	-0.15	-0.15	0.44	0.49	0.45	0.44	1.00	-	-	-	-
PTI	-0.11	0.04	-0.03	-0.12	-0.12	-0.01	0.02	0.02	0.03	0.76	0.83	0.74	0.62	0.75	1.00	-	-	-
λ Skew	-0.12	-0.08	-0.12	-0.12	-0.12	-0.13	-0.11	-0.11	-0.11	-0.01	0.00	0.00	0.05	0.38	0.07	1.00	-	-
λ Var	-0.19	-0.04	-0.12	-0.20	-0.20	-0.11	-0.07	-0.07	-0.07	0.63	0.69	0.61	0.51	0.88	0.89	0.27	1.00	-
TTI	-0.07	0.07	0.01	-0.08	-0.09	0.03	0.06	0.06	0.06	0.78	0.85	0.75	0.61	0.65	0.99	0.00	0.85	1.00

Table A-50: Performance Measures Correlation Matrix (2010) - Weekend (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.68	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.69	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.69	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.69	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.69	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.69	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.97	0.71	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.51	0.39	0.59	0.51	0.51	0.61	0.63	0.64	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.41	0.30	0.48	0.40	0.40	0.50	0.54	0.53	0.53	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.53	0.52	0.61	0.53	0.53	0.61	0.64	0.64	0.66	0.94	0.92	1.00	-	-	-	-	-	-
BT	0.57	0.56	0.64	0.58	0.58	0.64	0.66	0.67	0.69	0.85	0.80	0.97	1.00	-	-	-	-	-
BTI	-0.24	-0.04	-0.16	-0.22	-0.22	-0.15	-0.12	-0.12	-0.10	0.43	0.47	0.50	0.49	1.00	-	-	-	-
PTI	-0.11	-0.01	-0.03	-0.11	-0.11	0.00	0.02	0.02	0.03	0.73	0.79	0.68	0.54	0.75	1.00	-	-	-
λ Skew	-0.11	-0.05	-0.12	-0.12	-0.12	-0.13	-0.11	-0.11	-0.11	-0.02	-0.02	0.00	0.04	0.37	0.09	1.00	-	-
λ Var	-0.19	-0.11	-0.13	-0.20	-0.20	-0.11	-0.08	-0.08	-0.08	0.59	0.65	0.52	0.41	0.84	0.87	0.32	1.00	-
TTI	-0.07	0.00	0.00	-0.09	-0.09	0.03	0.05	0.05	0.05	0.75	0.81	0.67	0.51	0.63	0.99	0.01	0.82	1.00

Table A-51: Performance Measures Correlation Matrix (2010) - Weekend (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.59	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.56	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.56	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.55	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.58	1.00	0.98	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.95	0.59	0.99	0.96	0.96	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.83	0.63	0.90	0.85	0.85	0.86	0.89	0.93	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.34	0.39	0.44	0.34	0.34	0.39	0.50	0.58	0.70	1.00	-	-	-	-	-	-	-	-
TTV_85	0.34	0.33	0.44	0.34	0.34	0.42	0.51	0.56	0.60	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.22	0.42	0.32	0.22	0.22	0.25	0.33	0.43	0.71	0.83	0.65	1.00	-	-	-	-	-	-
BT	0.18	0.38	0.27	0.18	0.18	0.19	0.28	0.37	0.67	0.77	0.57	0.99	1.00	-	-	-	-	-
BTI	-0.02	0.25	0.07	-0.02	-0.02	0.00	0.07	0.17	0.49	0.65	0.44	0.92	0.94	1.00	-	-	-	-
PTI	-0.04	0.22	0.06	-0.04	-0.04	0.01	0.08	0.18	0.46	0.73	0.59	0.90	0.89	0.95	1.00	-	-	-
λ Skew	-0.06	0.15	-0.01	-0.07	-0.07	-0.07	0.01	0.09	0.26	0.51	0.34	0.57	0.59	0.64	0.59	1.00	-	-
λ Var	-0.07	0.17	0.02	-0.08	-0.08	-0.04	0.07	0.17	0.37	0.82	0.68	0.78	0.77	0.81	0.86	0.71	1.00	-
TTI	-0.07	0.11	0.02	-0.09	-0.09	0.02	0.07	0.12	0.23	0.66	0.75	0.54	0.47	0.50	0.73	0.28	0.66	1.00

Table A-52: Performance Measures Correlation Matrix (2010) - Weekend (9 PM - 10 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.37	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.42	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_10	0.98	0.38	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_15	0.98	0.38	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_50	0.98	0.37	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_85	0.97	0.37	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_Percentile_90	0.97	0.37	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_Percentile_95	0.97	0.37	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.35	0.10	0.42	0.34	0.34	0.44	0.48	0.48	0.48	1.00	-	-	-	-	-	-	-	-
TTV_85	0.23	0.06	0.30	0.22	0.21	0.32	0.36	0.36	0.36	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.38	0.13	0.45	0.37	0.37	0.47	0.51	0.51	0.51	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.31	-0.37	0.34	0.31	0.31	0.39	0.42	0.42	0.43	0.83	0.78	0.84	1.00	-	-	-	-	-
BTI	-0.29	-0.22	-0.24	-0.29	-0.29	-0.22	-0.19	-0.18	-0.18	0.52	0.54	0.52	0.55	1.00	-	-	-	-
PTI	-0.14	-0.03	-0.06	-0.14	-0.14	-0.03	-0.01	0.00	0.00	0.79	0.83	0.78	0.59	0.74	1.00	-	-	-
λ Skew	-0.07	0.03	-0.07	-0.07	-0.07	-0.08	-0.06	-0.06	-0.06	0.05	0.06	0.05	0.10	0.39	0.08	1.00	-	-
λ Var	-0.22	-0.06	-0.17	-0.24	-0.24	-0.15	-0.11	-0.11	-0.11	0.67	0.69	0.64	0.54	0.90	0.85	0.32	1.00	-
TTI	-0.09	0.04	-0.02	-0.10	-0.11	0.01	0.03	0.04	0.04	0.80	0.85	0.78	0.54	0.61	0.98	-0.01	0.78	1.00

Table A-53: Performance Measures Correlation Matrix (2010) - All (8 AM - 9 AM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.57	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.93	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.59	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.59	0.95	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.62	0.97	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.80	0.79	0.95	0.82	0.82	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.74	0.80	0.92	0.77	0.77	0.80	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.68	0.82	0.88	0.70	0.70	0.74	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.26	0.69	0.56	0.28	0.28	0.35	0.77	0.83	0.87	1.00	-	-	-	-	-	-	-	-
TTV_85	0.26	0.67	0.55	0.27	0.28	0.35	0.77	0.82	0.86	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.26	0.71	0.55	0.28	0.28	0.34	0.76	0.82	0.88	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.24	0.69	0.52	0.26	0.26	0.31	0.73	0.80	0.87	0.98	0.95	1.00	1.00	-	-	-	-	-
BTI	-0.03	0.47	0.20	-0.02	-0.02	0.03	0.36	0.43	0.53	0.66	0.62	0.72	0.74	1.00	-	-	-	-
PTI	-0.02	0.47	0.23	-0.02	-0.01	0.08	0.41	0.47	0.54	0.72	0.71	0.74	0.73	0.90	1.00	-	-	-
λ Skew	0.03	0.42	0.21	0.04	0.04	0.05	0.36	0.43	0.52	0.61	0.55	0.67	0.71	0.86	0.68	1.00	-	-
λ Var	0.00	0.52	0.27	0.01	0.01	0.08	0.48	0.55	0.62	0.81	0.80	0.83	0.83	0.93	0.94	0.81	1.00	-
TTI	-0.04	0.37	0.19	-0.04	-0.04	0.09	0.35	0.39	0.43	0.62	0.64	0.61	0.57	0.68	0.91	0.41	0.78	1.00

Table A-54: Performance Measures Correlation Matrix (2010) - All (12 PM - 1 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.58	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.91	0.67	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.91	0.67	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.91	0.67	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.91	0.66	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.91	0.66	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.90	0.66	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.90	0.66	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.33	0.57	0.50	0.50	0.60	0.61	0.62	0.62	1.00	-	-	-	-	-	-	-	-
TTV_85	0.39	0.26	0.50	0.42	0.42	0.53	0.54	0.55	0.54	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.49	0.37	0.60	0.53	0.53	0.63	0.64	0.65	0.65	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.56	0.33	0.67	0.62	0.62	0.70	0.71	0.72	0.72	0.94	0.91	0.96	1.00	-	-	-	-	-
BTI	-0.30	-0.32	-0.28	-0.33	-0.33	-0.26	-0.24	-0.23	-0.23	0.39	0.43	0.37	0.35	1.00	-	-	-	-
PTI	-0.12	-0.10	-0.06	-0.15	-0.15	-0.03	-0.01	-0.01	-0.01	0.74	0.79	0.72	0.59	0.76	1.00	-	-	-
λ Skew	-0.16	-0.07	-0.17	-0.16	-0.16	-0.18	-0.16	-0.16	-0.16	-0.07	-0.07	-0.07	-0.02	0.49	0.07	1.00	-	-
λ Var	-0.22	-0.21	-0.19	-0.26	-0.26	-0.17	-0.15	-0.15	-0.15	0.53	0.58	0.49	0.41	0.92	0.84	0.43	1.00	-
TTI	-0.08	-0.04	-0.02	-0.11	-0.11	0.02	0.03	0.04	0.03	0.76	0.82	0.74	0.59	0.66	0.99	-0.03	0.78	1.00

Table A-55: Performance Measures Correlation Matrix (2010) - All (5 PM - 6 PM)

MOE	MinTravel_Time	MaxTravel_Time	AvgTravel_Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.49	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.88	0.70	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.53	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.54	0.91	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.92	0.62	0.97	0.94	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.73	0.73	0.96	0.75	0.76	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.68	0.73	0.93	0.71	0.71	0.83	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.60	0.72	0.88	0.63	0.63	0.74	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.30	0.65	0.69	0.33	0.33	0.53	0.86	0.90	0.93	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.64	0.68	0.31	0.31	0.54	0.86	0.89	0.90	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.31	0.65	0.68	0.34	0.34	0.50	0.85	0.89	0.94	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.31	0.62	0.66	0.33	0.34	0.47	0.82	0.87	0.94	0.96	0.93	0.99	1.00	-	-	-	-	-
BTI	-0.09	0.42	0.19	-0.06	-0.06	0.03	0.33	0.40	0.47	0.57	0.52	0.60	0.61	1.00	-	-	-	-
PTI	-0.05	0.47	0.29	-0.03	-0.03	0.15	0.46	0.52	0.56	0.71	0.69	0.69	0.68	0.92	1.00	-	-	-
λ Skew	-0.04	0.28	0.12	-0.03	-0.03	-0.03	0.22	0.29	0.35	0.41	0.34	0.43	0.47	0.83	0.72	1.00	-	-
λ Var	-0.06	0.43	0.23	-0.04	-0.04	0.06	0.40	0.46	0.51	0.64	0.61	0.64	0.64	0.92	0.94	0.83	1.00	-
TTI	-0.08	0.41	0.28	-0.05	-0.05	0.20	0.44	0.47	0.47	0.66	0.67	0.60	0.55	0.69	0.90	0.44	0.76	1.00

Table A-56: Performance Measures Correlation Matrix (2010) - All (9 PM - 10 PM)

MOE	MinTravel_ Time	MaxTravel Time	AvgTravel _Time	TT_10th Percentile	TT_15th Percentile	TT_50th Percentile	TT_85th Percentile	TT_90th Percentile	TT_95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.39	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.94	0.41	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.94	0.40	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.94	0.40	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.94	0.40	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.93	0.40	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.93	0.39	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.93	0.39	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.41	0.15	0.51	0.44	0.44	0.53	0.57	0.57	0.57	1.00	-	-	-	-	-	-	-	-
TTV_85	0.30	0.12	0.40	0.32	0.32	0.42	0.46	0.46	0.46	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.46	0.19	0.56	0.49	0.49	0.57	0.61	0.61	0.62	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.50	0.08	0.60	0.54	0.54	0.61	0.64	0.65	0.66	0.90	0.85	0.95	1.00	-	-	-	-	-
BTI	-0.27	-0.15	-0.23	-0.28	-0.28	-0.22	-0.18	-0.18	-0.17	0.43	0.48	0.45	0.45	1.00	-	-	-	-
PTI	-0.15	-0.05	-0.07	-0.16	-0.16	-0.05	-0.02	-0.02	-0.01	0.74	0.81	0.70	0.55	0.75	1.00	-	-	-
λ Skew	-0.16	-0.08	-0.17	-0.17	-0.17	-0.18	-0.16	-0.16	-0.15	-0.03	-0.01	0.01	0.10	0.52	0.13	1.00	-	-
λ Var	-0.24	-0.09	-0.19	-0.26	-0.26	-0.18	-0.14	-0.14	-0.14	0.59	0.64	0.54	0.44	0.88	0.88	0.37	1.00	-
TTI	-0.11	-0.01	-0.03	-0.12	-0.12	-0.01	0.02	0.02	0.02	0.77	0.83	0.71	0.53	0.61	0.98	0.01	0.81	1.00

Table A-57: Performance Measures Correlation Matrix (2011) - Monday (8 AM - 9 AM)

MOE	MinTravel- Time	MaxTravel- Time	AvgTravel- Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.72	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.63	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.63	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.67	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.92	0.78	0.98	0.93	0.93	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.90	0.81	0.97	0.91	0.91	0.94	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.86	0.85	0.94	0.87	0.87	0.91	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.30	0.73	0.48	0.31	0.32	0.40	0.64	0.69	0.74	1.00	-	-	-	-	-	-	-	-
TTV_85	0.27	0.69	0.45	0.28	0.29	0.38	0.62	0.66	0.70	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.29	0.77	0.47	0.30	0.30	0.38	0.62	0.67	0.73	0.99	0.96	1.00	-	-	-	-	-	-
BT	0.27	0.77	0.44	0.28	0.28	0.36	0.59	0.65	0.72	0.97	0.93	0.99	1.00	-	-	-	-	-
BTI	-0.10	0.29	0.01	-0.09	-0.09	-0.05	0.12	0.16	0.23	0.53	0.49	0.57	0.60	1.00	-	-	-	-
PTI	-0.06	0.05	-0.02	-0.06	-0.06	-0.04	0.01	0.03	0.04	0.16	0.16	0.16	0.16	0.32	1.00	-	-	-
λ Skew	-0.04	0.22	0.00	-0.05	-0.05	-0.05	0.05	0.09	0.14	0.28	0.22	0.33	0.38	0.64	0.13	1.00	-	-
λ Var	-0.11	0.25	0.01	-0.10	-0.10	-0.05	0.13	0.17	0.22	0.56	0.55	0.56	0.56	0.89	0.33	0.70	1.00	-
TTI	-0.05	0.01	-0.03	-0.05	-0.05	-0.04	-0.01	0.00	0.00	0.08	0.08	0.07	0.07	0.19	0.99	0.04	0.20	1.00

Table A-58: Performance Measures Correlation Matrix (2011) - Monday (12 PM - 1 PM)

MOE	MinTravel- Time	MaxTravel- Time	AvgTravel- Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.87	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.87	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.88	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.88	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.89	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.89	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.63	0.71	0.69	0.64	0.65	0.68	0.73	0.74	0.75	1.00	-	-	-	-	-	-	-	-
TTV_85	0.62	0.69	0.68	0.63	0.64	0.67	0.72	0.73	0.74	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.61	0.71	0.67	0.63	0.63	0.66	0.71	0.72	0.74	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.57	0.67	0.64	0.59	0.60	0.63	0.67	0.69	0.71	0.95	0.93	0.99	1.00	-	-	-	-	-
BTI	-0.16	-0.10	-0.13	-0.15	-0.15	-0.14	-0.11	-0.11	-0.09	0.17	0.17	0.22	0.26	1.00	-	-	-	-
PTI	-0.06	-0.05	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	0.02	0.02	0.02	0.02	0.29	1.00	-	-	-
λ Skew	-0.09	-0.07	-0.08	-0.09	-0.09	-0.09	-0.07	-0.07	-0.07	0.05	0.07	0.05	0.07	0.48	0.09	1.00	-	-
λ Var	-0.16	-0.11	-0.14	-0.16	-0.16	-0.15	-0.12	-0.11	-0.10	0.16	0.18	0.17	0.18	0.87	0.29	0.78	1.00	-
TTI	-0.05	-0.04	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.01	0.01	0.00	0.20	1.00	0.04	0.21	1.00

Table A-59: Performance Measures Correlation Matrix (2011) - Monday (5 PM - 6 PM)

MOE	MinTravel- Time	MaxTravel- Time	AvgTravel- Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.64	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.65	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.69	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.94	0.76	0.99	0.95	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.92	0.79	0.98	0.94	0.94	0.97	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.88	0.83	0.96	0.90	0.91	0.94	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.33	0.72	0.52	0.36	0.38	0.48	0.62	0.66	0.72	1.00	-	-	-	-	-	-	-	-
TTV_85	0.33	0.70	0.52	0.36	0.38	0.48	0.62	0.66	0.71	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.31	0.77	0.49	0.34	0.35	0.44	0.58	0.63	0.71	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.28	0.76	0.45	0.31	0.32	0.40	0.54	0.60	0.68	0.94	0.91	0.99	1.00	-	-	-	-	-
BTI	-0.18	0.22	-0.09	-0.17	-0.16	-0.13	-0.03	0.01	0.09	0.38	0.36	0.47	0.52	1.00	-	-	-	-
PTI	-0.07	0.05	-0.05	-0.07	-0.07	-0.05	-0.03	-0.02	0.00	0.11	0.10	0.12	0.12	0.28	1.00	-	-	-
λ Skew	-0.10	0.13	-0.08	-0.10	-0.11	-0.11	-0.05	-0.02	0.02	0.17	0.14	0.23	0.28	0.62	0.13	1.00	-	-
λ Var	-0.16	0.17	-0.08	-0.15	-0.15	-0.11	-0.01	0.03	0.08	0.40	0.40	0.43	0.45	0.86	0.32	0.75	1.00	-
TTI	-0.05	0.01	-0.04	-0.05	-0.05	-0.04	-0.03	-0.02	-0.02	0.04	0.05	0.04	0.04	0.13	0.99	0.03	0.19	1.00

Table A-60: Performance Measures Correlation Matrix (2011) - Monday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.90	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.90	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.90	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.90	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.91	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.91	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.65	0.69	0.69	0.66	0.66	0.68	0.72	0.73	0.74	1.00	-	-	-	-	-	-	-	-
TTV_85	0.55	0.59	0.58	0.55	0.55	0.57	0.61	0.62	0.63	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.66	0.70	0.70	0.68	0.67	0.69	0.72	0.73	0.75	0.97	0.92	1.00	-	-	-	-	-	-
BT	0.64	0.67	0.68	0.66	0.66	0.67	0.70	0.72	0.74	0.92	0.84	0.98	1.00	-	-	-	-	-
BTI	-0.16	-0.11	-0.14	-0.15	-0.15	-0.15	-0.12	-0.12	-0.11	0.20	0.23	0.21	0.23	1.00	-	-	-	-
PTI	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	0.02	0.04	0.02	0.01	0.30	1.00	-	-	-
λ Skew	-0.06	-0.05	-0.06	-0.06	-0.06	-0.07	-0.04	-0.04	-0.04	0.15	0.19	0.13	0.14	0.62	0.07	1.00	-	-
λ Var	-0.17	-0.13	-0.16	-0.17	-0.17	-0.17	-0.14	-0.14	-0.13	0.17	0.23	0.13	0.11	0.88	0.26	0.78	1.00	-
TTI	-0.04	-0.04	-0.04	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.03	0.01	0.00	0.25	1.00	0.03	0.21	1.00

Table A-61: Performance Measures Correlation Matrix (2011) - Wednesday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.49	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.50	0.97	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.50	0.97	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.53	0.99	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.90	0.67	0.98	0.91	0.91	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.87	0.73	0.96	0.88	0.88	0.93	0.99	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.79	0.81	0.91	0.79	0.80	0.85	0.95	0.98	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.29	0.73	0.50	0.30	0.30	0.42	0.66	0.72	0.80	1.00	-	-	-	-	-	-	-	-
TTV_85	0.27	0.64	0.49	0.28	0.28	0.41	0.65	0.70	0.76	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.78	0.45	0.25	0.25	0.36	0.60	0.67	0.79	0.97	0.93	1.00	-	-	-	-	-	-
BT	0.22	0.79	0.42	0.23	0.23	0.32	0.56	0.64	0.77	0.94	0.88	0.99	1.00	-	-	-	-	-
BTI	-0.08	0.41	0.05	-0.07	-0.07	-0.03	0.15	0.22	0.35	0.54	0.48	0.64	0.67	1.00	-	-	-	-
PTI	-0.05	0.08	-0.01	-0.05	-0.05	-0.03	0.02	0.03	0.06	0.13	0.13	0.15	0.15	0.29	1.00	-	-	-
λ Skew	-0.02	0.39	0.05	-0.02	-0.03	-0.03	0.11	0.18	0.28	0.39	0.31	0.47	0.52	0.71	0.13	1.00	-	-
λ Var	-0.09	0.33	0.05	-0.08	-0.08	-0.03	0.17	0.23	0.32	0.57	0.54	0.59	0.60	0.84	0.27	0.77	1.00	-
TTI	-0.05	0.03	-0.02	-0.04	-0.04	-0.03	0.00	0.00	0.01	0.07	0.07	0.07	0.06	0.17	0.99	0.04	0.16	1.00

Table A-62: Performance Measures Correlation Matrix (2011) - Wednesday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.94	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.94	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.95	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.95	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.96	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.96	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.63	0.75	0.69	0.64	0.65	0.68	0.72	0.74	0.75	1.00	-	-	-	-	-	-	-	-
TTV_85	0.65	0.75	0.71	0.66	0.66	0.70	0.74	0.75	0.77	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.61	0.74	0.67	0.63	0.63	0.66	0.71	0.72	0.74	0.99	0.98	1.00	-	-	-	-	-	-
BT	0.58	0.72	0.64	0.59	0.60	0.63	0.67	0.69	0.71	0.97	0.95	0.99	1.00	-	-	-	-	-
BTI	-0.17	-0.08	-0.14	-0.16	-0.16	-0.15	-0.12	-0.11	-0.09	0.19	0.18	0.22	0.26	1.00	-	-	-	-
PTI	-0.06	-0.05	-0.05	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	0.02	0.03	0.02	0.02	0.26	1.00	-	-	-
λ Skew	-0.09	-0.07	-0.09	-0.09	-0.09	-0.10	-0.07	-0.07	-0.07	0.06	0.08	0.06	0.08	0.56	0.08	1.00	-	-
λ Var	-0.16	-0.09	-0.13	-0.15	-0.15	-0.14	-0.11	-0.10	-0.09	0.19	0.19	0.19	0.20	0.89	0.28	0.77	1.00	-
TTI	-0.05	-0.04	-0.04	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.01	0.01	0.00	0.17	1.00	0.02	0.20	1.00

Table A-63: Performance Measures Correlation Matrix (2011) - Wednesday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.75	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.65	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.66	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.71	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.90	0.79	0.99	0.93	0.94	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.87	0.82	0.97	0.91	0.91	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.82	0.87	0.94	0.86	0.86	0.92	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.27	0.74	0.52	0.33	0.35	0.47	0.65	0.70	0.76	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.70	0.53	0.35	0.36	0.49	0.66	0.71	0.75	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.77	0.48	0.30	0.31	0.42	0.60	0.66	0.75	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.20	0.77	0.43	0.26	0.27	0.38	0.55	0.62	0.71	0.95	0.90	0.99	1.00	-	-	-	-	-
BTI	-0.19	0.27	-0.10	-0.18	-0.18	-0.15	-0.04	0.02	0.13	0.36	0.28	0.47	0.53	1.00	-	-	-	-
PTI	-0.07	0.03	-0.05	-0.07	-0.07	-0.06	-0.03	-0.02	0.01	0.08	0.07	0.10	0.11	0.31	1.00	-	-	-
λ Skew	-0.13	0.17	-0.10	-0.14	-0.14	-0.14	-0.08	-0.03	0.03	0.15	0.09	0.24	0.29	0.70	0.12	1.00	-	-
λ Var	-0.19	0.23	-0.09	-0.18	-0.18	-0.13	-0.01	0.05	0.12	0.40	0.35	0.46	0.50	0.90	0.26	0.75	1.00	-
TTI	-0.06	0.00	-0.04	-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	0.05	0.05	0.06	0.06	0.21	0.99	0.05	0.18	1.00

Table A-64: Performance Measures Correlation Matrix (2011) - Wednesday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.82	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.82	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.83	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.83	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.83	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.84	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.62	0.63	0.65	0.62	0.62	0.64	0.68	0.69	0.71	1.00	-	-	-	-	-	-	-	-
TTV_85	0.58	0.59	0.61	0.58	0.58	0.60	0.64	0.65	0.67	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.59	0.62	0.62	0.60	0.59	0.61	0.65	0.67	0.69	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.55	0.57	0.58	0.56	0.56	0.56	0.61	0.63	0.65	0.92	0.87	0.98	1.00	-	-	-	-	-
BTI	-0.14	-0.09	-0.13	-0.14	-0.14	-0.14	-0.11	-0.10	-0.08	0.24	0.26	0.27	0.30	1.00	-	-	-	-
PTI	-0.05	-0.04	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	0.03	0.04	0.02	0.01	0.28	1.00	-	-	-
λ Skew	-0.07	-0.05	-0.07	-0.07	-0.07	-0.08	-0.05	-0.05	-0.05	0.15	0.19	0.13	0.15	0.76	0.08	1.00	-	-
λ Var	-0.16	-0.10	-0.14	-0.16	-0.16	-0.15	-0.13	-0.12	-0.12	0.18	0.23	0.15	0.14	0.90	0.26	0.88	1.00	-
TTI	-0.04	-0.03	-0.04	-0.04	-0.05	-0.04	-0.04	-0.04	-0.04	0.02	0.03	0.01	0.00	0.23	1.00	0.03	0.21	1.00

Table A-65: Performance Measures Correlation Matrix (2011) - Friday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.71	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.72	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.72	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.76	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.78	0.99	0.98	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.94	0.81	0.97	0.95	0.95	0.96	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.49	0.67	0.56	0.50	0.50	0.52	0.63	0.68	0.73	1.00	-	-	-	-	-	-	-	-
TTV_85	0.54	0.68	0.61	0.55	0.55	0.57	0.67	0.71	0.76	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.43	0.69	0.50	0.44	0.44	0.45	0.56	0.62	0.69	0.97	0.93	1.00	-	-	-	-	-	-
BT	0.35	0.64	0.43	0.36	0.36	0.37	0.49	0.55	0.63	0.94	0.89	0.99	1.00	-	-	-	-	-
BTI	-0.10	0.20	-0.05	-0.10	-0.09	-0.09	0.00	0.05	0.12	0.52	0.47	0.59	0.63	1.00	-	-	-	-
PTI	-0.05	0.01	-0.04	-0.05	-0.05	-0.05	-0.03	-0.03	-0.01	0.08	0.08	0.09	0.09	0.34	1.00	-	-	-
λ Skew	-0.06	0.16	-0.03	-0.06	-0.06	-0.07	0.03	0.06	0.11	0.45	0.43	0.48	0.51	0.74	0.12	1.00	-	-
λ Var	-0.12	0.12	-0.07	-0.12	-0.12	-0.11	-0.02	0.02	0.07	0.48	0.47	0.48	0.49	0.87	0.27	0.83	1.00	-
TTI	-0.05	-0.01	-0.04	-0.05	-0.05	-0.05	-0.04	-0.04	-0.03	0.03	0.03	0.04	0.03	0.25	1.00	0.05	0.20	1.00

Table A-66: Performance Measures Correlation Matrix (2011) - Friday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.81	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.83	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.83	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.86	1.00	0.98	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.87	0.99	0.98	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.95	0.89	0.98	0.96	0.96	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.54	0.70	0.65	0.57	0.58	0.63	0.71	0.73	0.76	1.00	-	-	-	-	-	-	-	-
TTV_85	0.53	0.68	0.64	0.56	0.57	0.62	0.70	0.72	0.75	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.51	0.74	0.62	0.54	0.55	0.59	0.67	0.70	0.75	0.97	0.96	1.00	-	-	-	-	-	-
BT	0.48	0.72	0.58	0.51	0.52	0.56	0.64	0.67	0.72	0.94	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.11	0.09	-0.06	-0.10	-0.10	-0.08	-0.03	-0.01	0.04	0.30	0.28	0.38	0.41	1.00	-	-	-	-
PTI	-0.06	-0.02	-0.05	-0.06	-0.05	-0.05	-0.04	-0.04	-0.03	0.04	0.04	0.05	0.05	0.26	1.00	-	-	-
λ Skew	-0.10	-0.06	-0.09	-0.10	-0.10	-0.10	-0.07	-0.06	-0.06	0.07	0.07	0.07	0.08	0.51	0.08	1.00	-	-
λ Var	-0.13	-0.03	-0.09	-0.12	-0.12	-0.10	-0.05	-0.04	-0.02	0.26	0.26	0.25	0.25	0.82	0.29	0.76	1.00	-
TTI	-0.04	-0.02	-0.04	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	0.01	0.02	0.01	0.01	0.15	0.99	0.02	0.19	1.00

Table A-67: Performance Measures Correlation Matrix (2011) - Friday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.53	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.92	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.57	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.59	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.94	0.68	1.00	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.83	0.78	0.98	0.86	0.88	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.78	0.80	0.96	0.82	0.84	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.73	0.84	0.93	0.77	0.80	0.89	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.26	0.74	0.59	0.30	0.35	0.53	0.74	0.80	0.83	1.00	-	-	-	-	-	-	-	-
TTV_85	0.26	0.72	0.59	0.30	0.35	0.53	0.75	0.79	0.83	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.77	0.57	0.29	0.33	0.50	0.72	0.78	0.84	0.98	0.97	1.00	-	-	-	-	-	-
BT	0.23	0.76	0.55	0.28	0.32	0.48	0.70	0.76	0.82	0.96	0.95	0.99	1.00	-	-	-	-	-
BTI	-0.16	0.27	-0.01	-0.14	-0.13	-0.07	0.07	0.12	0.21	0.35	0.34	0.45	0.49	1.00	-	-	-	-
PTI	-0.07	0.07	-0.01	-0.06	-0.06	-0.03	0.02	0.03	0.06	0.12	0.12	0.14	0.15	0.37	1.00	-	-	-
λ Skew	-0.12	0.09	-0.09	-0.12	-0.13	-0.13	-0.05	-0.02	0.02	0.10	0.07	0.15	0.19	0.66	0.12	1.00	-	-
λ Var	-0.14	0.29	0.03	-0.12	-0.11	-0.03	0.13	0.18	0.25	0.43	0.43	0.48	0.51	0.88	0.30	0.74	1.00	-
TTI	-0.06	0.06	-0.01	-0.05	-0.05	-0.02	0.02	0.03	0.04	0.10	0.11	0.11	0.11	0.28	0.99	0.05	0.23	1.00

Table A-68: Performance Measures Correlation Matrix (2011) - Friday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.83	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.83	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.84	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.59	0.61	0.63	0.60	0.60	0.62	0.65	0.67	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.57	0.58	0.61	0.58	0.58	0.61	0.64	0.65	0.66	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.58	0.60	0.61	0.58	0.58	0.61	0.64	0.65	0.67	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.52	0.54	0.56	0.53	0.53	0.55	0.58	0.60	0.62	0.91	0.84	0.97	1.00	-	-	-	-	-
BTI	-0.16	-0.12	-0.15	-0.16	-0.16	-0.16	-0.13	-0.12	-0.11	0.22	0.24	0.26	0.30	1.00	-	-	-	-
PTI	-0.05	-0.02	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	0.02	0.04	0.02	0.01	0.27	1.00	-	-	-
λ Skew	-0.09	-0.07	-0.09	-0.09	-0.09	-0.10	-0.08	-0.08	-0.08	0.09	0.13	0.08	0.11	0.68	0.07	1.00	-	-
λ Var	-0.16	-0.11	-0.15	-0.17	-0.17	-0.16	-0.14	-0.13	-0.13	0.19	0.24	0.17	0.17	0.89	0.26	0.84	1.00	-
TTI	-0.04	-0.02	-0.04	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.03	0.01	0.00	0.22	1.00	0.03	0.21	1.00

Table A-69: Performance Measures Correlation Matrix (2011) - Saturday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.92	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.93	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.74	0.79	0.78	0.75	0.75	0.78	0.80	0.80	0.81	1.00	-	-	-	-	-	-	-	-
TTV_85	0.68	0.73	0.71	0.68	0.68	0.71	0.73	0.74	0.74	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.66	0.72	0.70	0.67	0.67	0.70	0.71	0.72	0.74	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.61	0.68	0.66	0.63	0.63	0.65	0.67	0.68	0.70	0.93	0.87	0.97	1.00	-	-	-	-	-
BTI	-0.19	-0.13	-0.17	-0.18	-0.18	-0.18	-0.16	-0.15	-0.15	0.08	0.11	0.12	0.16	1.00	-	-	-	-
PTI	-0.06	-0.04	-0.05	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	0.01	0.03	0.01	0.01	0.30	1.00	-	-	-
λ Skew	-0.10	-0.07	-0.09	-0.10	-0.10	-0.10	-0.08	-0.08	-0.08	0.07	0.11	0.07	0.10	0.63	0.08	1.00	-	-
λ Var	-0.17	-0.12	-0.16	-0.17	-0.17	-0.16	-0.14	-0.14	-0.14	0.11	0.16	0.11	0.11	0.89	0.27	0.84	1.00	-
TTI	-0.05	-0.03	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.02	0.01	0.00	0.24	1.00	0.04	0.22	1.00

Table A-70: Performance Measures Correlation Matrix (2011) - Saturday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.66	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.68	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.66	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.66	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.67	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.67	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.67	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.68	0.99	0.98	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.63	0.51	0.69	0.64	0.64	0.69	0.72	0.74	0.75	1.00	-	-	-	-	-	-	-	-
TTV_85	0.60	0.49	0.66	0.61	0.61	0.66	0.69	0.71	0.72	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.56	0.53	0.62	0.57	0.57	0.61	0.64	0.66	0.70	0.91	0.90	1.00	-	-	-	-	-	-
BT	0.48	0.41	0.54	0.49	0.50	0.53	0.56	0.57	0.63	0.82	0.80	0.97	1.00	-	-	-	-	-
BTI	-0.12	-0.10	-0.10	-0.12	-0.12	-0.10	-0.08	-0.07	-0.02	0.18	0.18	0.36	0.45	1.00	-	-	-	-
PTI	-0.05	-0.04	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	0.02	0.03	0.03	0.04	0.28	1.00	-	-	-
λ Skew	-0.13	-0.10	-0.12	-0.13	-0.13	-0.13	-0.11	-0.11	-0.11	0.01	0.04	0.01	0.03	0.52	0.07	1.00	-	-
λ Var	-0.15	-0.11	-0.13	-0.15	-0.15	-0.13	-0.11	-0.10	-0.10	0.18	0.20	0.14	0.14	0.74	0.26	0.80	1.00	-
TTI	-0.05	-0.03	-0.04	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.01	0.02	0.01	0.00	0.21	1.00	0.03	0.22	1.00

Table A-71: Performance Measures Correlation Matrix (2011) - Saturday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.60	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.60	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.60	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.61	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.61	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.70	0.97	0.96	0.96	0.97	0.97	0.97	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.57	0.44	0.62	0.57	0.57	0.62	0.65	0.67	0.67	1.00	-	-	-	-	-	-	-	-
TTV_85	0.54	0.38	0.60	0.54	0.55	0.61	0.63	0.64	0.63	0.95	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.62	0.38	0.33	0.33	0.36	0.38	0.39	0.57	0.62	0.53	1.00	-	-	-	-	-	-
BT	0.22	0.56	0.26	0.22	0.22	0.23	0.25	0.27	0.47	0.46	0.34	0.97	1.00	-	-	-	-	-
BTI	-0.11	0.16	-0.08	-0.11	-0.11	-0.10	-0.08	-0.05	0.07	0.31	0.17	0.58	0.62	1.00	-	-	-	-
PTI	-0.05	-0.01	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.02	0.05	0.04	0.07	0.08	0.26	1.00	-	-	-
λ Skew	-0.11	-0.02	-0.10	-0.11	-0.11	-0.11	-0.08	-0.07	-0.05	0.19	0.13	0.17	0.19	0.63	0.10	1.00	-	-
λ Var	-0.15	-0.07	-0.13	-0.15	-0.15	-0.14	-0.11	-0.10	-0.07	0.27	0.22	0.20	0.20	0.75	0.28	0.88	1.00	-
TTI	-0.04	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	0.02	0.03	0.02	0.01	0.16	0.99	0.04	0.20	1.00

Table A-72: Performance Measures Correlation Matrix (2011) - Saturday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.85	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	1.00	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	1.00	0.86	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	1.00	0.86	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	1.00	0.86	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.87	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.63	0.66	0.66	0.63	0.63	0.66	0.68	0.69	0.71	1.00	-	-	-	-	-	-	-	-
TTV_85	0.48	0.52	0.51	0.48	0.47	0.52	0.53	0.54	0.55	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.58	0.65	0.61	0.59	0.58	0.61	0.63	0.64	0.68	0.93	0.83	1.00	-	-	-	-	-	-
BT	0.56	0.62	0.59	0.57	0.57	0.58	0.60	0.62	0.67	0.84	0.69	0.97	1.00	-	-	-	-	-
BTI	-0.14	-0.07	-0.13	-0.14	-0.14	-0.13	-0.11	-0.10	-0.09	0.26	0.30	0.26	0.27	1.00	-	-	-	-
PTI	-0.05	-0.01	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	0.04	0.06	0.03	0.02	0.28	1.00	-	-	-
λ Skew	-0.08	-0.06	-0.07	-0.08	-0.08	-0.08	-0.06	-0.06	-0.06	0.12	0.17	0.09	0.10	0.64	0.07	1.00	-	-
λ Var	-0.15	-0.09	-0.14	-0.16	-0.16	-0.15	-0.12	-0.12	-0.11	0.24	0.34	0.17	0.14	0.89	0.26	0.79	1.00	-
TTI	-0.05	0.00	-0.04	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	0.03	0.05	0.02	0.00	0.23	1.00	0.03	0.22	1.00

Table A-73: Performance Measures Correlation Matrix (2011) - Weekday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.76	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.76	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.78	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.81	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.82	0.99	0.98	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.94	0.85	0.98	0.96	0.96	0.97	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.31	0.64	0.43	0.35	0.36	0.40	0.50	0.54	0.60	1.00	-	-	-	-	-	-	-	-
TTV_85	0.31	0.62	0.44	0.35	0.36	0.41	0.50	0.54	0.60	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.26	0.63	0.38	0.30	0.30	0.35	0.44	0.49	0.56	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.22	0.60	0.34	0.26	0.27	0.31	0.40	0.46	0.53	0.97	0.92	1.00	1.00	-	-	-	-	-
BTI	-0.35	-0.05	-0.29	-0.34	-0.34	-0.31	-0.24	-0.20	-0.15	0.44	0.43	0.48	0.51	1.00	-	-	-	-
PTI	-0.33	-0.06	-0.28	-0.33	-0.32	-0.30	-0.23	-0.20	-0.15	0.40	0.41	0.43	0.45	0.98	1.00	-	-	-
λ Skew	-0.11	0.00	-0.10	-0.11	-0.11	-0.11	-0.07	-0.06	-0.05	0.17	0.17	0.17	0.19	0.58	0.65	1.00	-	-
λ Var	-0.31	-0.07	-0.26	-0.30	-0.30	-0.28	-0.21	-0.19	-0.15	0.38	0.38	0.38	0.40	0.91	0.96	0.79	1.00	-
TTI	-0.37	-0.09	-0.31	-0.37	-0.36	-0.33	-0.27	-0.24	-0.20	0.38	0.40	0.40	0.40	0.92	0.97	0.57	0.93	1.00

Table A-74: Performance Measures Correlation Matrix (2011) - Weekday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.85	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.87	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.87	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.88	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.89	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.90	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.91	0.99	0.98	0.98	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.35	0.59	0.46	0.40	0.41	0.45	0.51	0.52	0.56	1.00	-	-	-	-	-	-	-	-
TTV_85	0.36	0.59	0.47	0.41	0.42	0.46	0.52	0.53	0.57	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.25	0.53	0.36	0.29	0.30	0.35	0.40	0.42	0.47	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.17	0.47	0.28	0.22	0.22	0.26	0.32	0.35	0.39	0.92	0.88	0.98	1.00	-	-	-	-	-
BTI	-0.40	-0.22	-0.36	-0.40	-0.39	-0.37	-0.34	-0.32	-0.29	0.31	0.27	0.41	0.47	1.00	-	-	-	-
PTI	-0.38	-0.21	-0.34	-0.37	-0.37	-0.35	-0.31	-0.30	-0.27	0.29	0.27	0.37	0.41	0.98	1.00	-	-	-
λ Skew	-0.13	-0.09	-0.13	-0.13	-0.13	-0.14	-0.12	-0.12	-0.11	0.04	0.04	0.07	0.10	0.54	0.61	1.00	-	-
λ Var	-0.34	-0.21	-0.31	-0.34	-0.34	-0.32	-0.28	-0.27	-0.25	0.27	0.25	0.32	0.35	0.92	0.97	0.75	1.00	-
TTI	-0.39	-0.22	-0.35	-0.39	-0.38	-0.36	-0.32	-0.31	-0.28	0.32	0.32	0.38	0.40	0.93	0.97	0.53	0.94	1.00

Table A-75: Performance Measures Correlation Matrix (2011) - Weekday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.60	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.70	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.63	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.64	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.67	1.00	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.94	0.73	0.99	0.96	0.97	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.92	0.75	0.98	0.95	0.96	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.88	0.79	0.96	0.91	0.92	0.95	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.13	0.59	0.32	0.19	0.20	0.28	0.44	0.48	0.56	1.00	-	-	-	-	-	-	-	-
TTV_85	0.13	0.57	0.33	0.19	0.20	0.29	0.44	0.48	0.56	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.09	0.62	0.28	0.14	0.15	0.23	0.39	0.43	0.53	0.97	0.96	1.00	-	-	-	-	-	-
BT	0.06	0.60	0.24	0.11	0.12	0.19	0.35	0.40	0.50	0.95	0.93	0.99	1.00	-	-	-	-	-
BTI	-0.35	0.11	-0.26	-0.34	-0.33	-0.29	-0.18	-0.14	-0.05	0.52	0.50	0.59	0.61	1.00	-	-	-	-
PTI	-0.32	0.09	-0.23	-0.31	-0.30	-0.26	-0.14	-0.11	-0.03	0.53	0.52	0.57	0.58	0.97	1.00	-	-	-
λ Skew	-0.19	0.03	-0.17	-0.19	-0.19	-0.19	-0.14	-0.12	-0.09	0.15	0.12	0.19	0.23	0.56	0.51	1.00	-	-
λ Var	-0.33	0.06	-0.23	-0.32	-0.31	-0.26	-0.14	-0.11	-0.04	0.54	0.53	0.56	0.56	0.92	0.95	0.64	1.00	-
TTI	-0.33	0.07	-0.22	-0.32	-0.31	-0.25	-0.14	-0.11	-0.03	0.56	0.57	0.58	0.57	0.90	0.97	0.41	0.94	1.00

Table A-76: Performance Measures Correlation Matrix (2011) - Weekday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.84	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.84	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.84	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.47	0.53	0.52	0.49	0.49	0.51	0.54	0.55	0.57	1.00	-	-	-	-	-	-	-	-
TTV_85	0.34	0.44	0.39	0.36	0.36	0.38	0.42	0.43	0.44	0.92	1.00	-	-	-	-	-	-	-
TTV_95	0.26	0.40	0.31	0.29	0.28	0.30	0.34	0.35	0.37	0.90	0.94	1.00	-	-	-	-	-	-
BT	0.19	0.33	0.24	0.22	0.21	0.23	0.26	0.28	0.30	0.86	0.86	0.97	1.00	-	-	-	-	-
BTI	-0.26	-0.16	-0.24	-0.26	-0.26	-0.25	-0.23	-0.22	-0.21	0.30	0.35	0.45	0.50	1.00	-	-	-	-
PTI	-0.22	-0.14	-0.21	-0.22	-0.22	-0.22	-0.20	-0.19	-0.18	0.23	0.30	0.34	0.36	0.95	1.00	-	-	-
λ Skew	-0.10	-0.09	-0.11	-0.11	-0.11	-0.11	-0.10	-0.10	-0.09	0.09	0.13	0.12	0.14	0.74	0.82	1.00	-	-
λ Var	-0.19	-0.12	-0.18	-0.19	-0.19	-0.18	-0.16	-0.16	-0.15	0.21	0.25	0.25	0.27	0.88	0.96	0.91	1.00	-
TTI	-0.22	-0.12	-0.21	-0.22	-0.22	-0.21	-0.19	-0.19	-0.18	0.19	0.29	0.28	0.25	0.80	0.93	0.64	0.86	1.00

Table A-77: Performance Measures Correlation Matrix (2011) - Weekend (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.95	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.95	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.95	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.95	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.95	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.95	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.59	0.67	0.65	0.62	0.62	0.64	0.67	0.67	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.53	0.60	0.57	0.54	0.54	0.56	0.60	0.60	0.60	0.95	1.00	-	-	-	-	-	-	-
TTV_95	0.50	0.61	0.55	0.52	0.52	0.54	0.57	0.58	0.59	0.94	0.92	1.00	-	-	-	-	-	-
BT	0.44	0.55	0.49	0.47	0.47	0.48	0.51	0.52	0.54	0.86	0.79	0.96	1.00	-	-	-	-	-
BTI	-0.28	-0.22	-0.26	-0.28	-0.28	-0.27	-0.25	-0.25	-0.24	0.12	0.13	0.23	0.29	1.00	-	-	-	-
PTI	-0.23	-0.19	-0.23	-0.24	-0.24	-0.23	-0.21	-0.21	-0.20	0.11	0.14	0.17	0.19	0.96	1.00	-	-	-
λ Skew	-0.12	-0.11	-0.12	-0.12	-0.13	-0.13	-0.11	-0.11	-0.11	0.06	0.09	0.08	0.10	0.70	0.73	1.00	-	-
λ Var	-0.20	-0.17	-0.20	-0.21	-0.21	-0.20	-0.18	-0.18	-0.18	0.12	0.14	0.13	0.14	0.90	0.96	0.82	1.00	-
TTI	-0.23	-0.19	-0.22	-0.23	-0.23	-0.22	-0.21	-0.21	-0.20	0.11	0.18	0.16	0.13	0.85	0.95	0.62	0.89	1.00

Table A-78: Performance Measures Correlation Matrix (2011) - Weekend (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.91	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.91	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.93	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.93	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.94	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.46	0.64	0.53	0.47	0.48	0.52	0.56	0.58	0.59	1.00	-	-	-	-	-	-	-	-
TTV_85	0.44	0.62	0.51	0.45	0.45	0.50	0.54	0.55	0.57	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.40	0.62	0.47	0.42	0.42	0.47	0.51	0.52	0.54	0.96	0.95	1.00	-	-	-	-	-	-
BT	0.34	0.55	0.41	0.36	0.37	0.40	0.45	0.46	0.49	0.92	0.85	0.96	1.00	-	-	-	-	-
BTI	-0.29	-0.14	-0.26	-0.29	-0.29	-0.27	-0.24	-0.23	-0.21	0.28	0.25	0.36	0.43	1.00	-	-	-	-
PTI	-0.23	-0.09	-0.20	-0.23	-0.23	-0.20	-0.18	-0.17	-0.16	0.31	0.31	0.35	0.37	0.94	1.00	-	-	-
λ Skew	-0.12	-0.11	-0.12	-0.13	-0.13	-0.13	-0.11	-0.11	-0.11	0.05	0.04	0.05	0.10	0.68	0.70	1.00	-	-
λ Var	-0.20	-0.10	-0.17	-0.20	-0.20	-0.18	-0.15	-0.15	-0.14	0.29	0.28	0.28	0.29	0.85	0.95	0.79	1.00	-
TTI	-0.17	-0.02	-0.14	-0.17	-0.17	-0.14	-0.12	-0.11	-0.10	0.37	0.42	0.39	0.34	0.76	0.92	0.49	0.86	1.00

Table A-79: Performance Measures Correlation Matrix (2011) - Weekend (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.83	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.83	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.84	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.85	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.87	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.49	0.60	0.55	0.50	0.51	0.55	0.58	0.59	0.60	1.00	-	-	-	-	-	-	-	-
TTV_85	0.45	0.52	0.51	0.46	0.46	0.51	0.54	0.55	0.55	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.35	0.61	0.41	0.36	0.36	0.40	0.43	0.44	0.49	0.86	0.78	1.00	-	-	-	-	-	-
BT	0.23	0.54	0.28	0.25	0.25	0.27	0.30	0.31	0.38	0.69	0.57	0.95	1.00	-	-	-	-	-
BTI	-0.21	0.08	-0.19	-0.21	-0.21	-0.20	-0.18	-0.17	-0.11	0.20	0.12	0.56	0.70	1.00	-	-	-	-
PTI	-0.19	0.07	-0.17	-0.19	-0.19	-0.18	-0.16	-0.15	-0.10	0.24	0.19	0.54	0.63	0.97	1.00	-	-	-
λ Skew	-0.11	-0.04	-0.11	-0.12	-0.12	-0.12	-0.11	-0.10	-0.08	0.08	0.05	0.16	0.23	0.59	0.67	1.00	-	-
λ Var	-0.18	-0.07	-0.17	-0.19	-0.18	-0.17	-0.15	-0.14	-0.13	0.25	0.23	0.30	0.31	0.68	0.81	0.85	1.00	-
TTI	-0.20	0.00	-0.18	-0.20	-0.20	-0.18	-0.16	-0.15	-0.13	0.31	0.33	0.44	0.43	0.74	0.87	0.58	0.86	1.00

Table A-80: Performance Measures Correlation Matrix (2011) - Weekend (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.62	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.62	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.62	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.62	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.62	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.62	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.60	0.41	0.64	0.61	0.61	0.62	0.67	0.68	0.69	1.00	-	-	-	-	-	-	-	-
TTV_85	0.54	0.37	0.57	0.54	0.54	0.55	0.61	0.61	0.62	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.54	0.38	0.58	0.55	0.55	0.56	0.61	0.62	0.64	0.93	0.88	1.00	-	-	-	-	-	-
BT	0.48	0.30	0.52	0.50	0.50	0.51	0.55	0.56	0.59	0.86	0.78	0.98	1.00	-	-	-	-	-
BTI	-0.20	-0.14	-0.19	-0.20	-0.20	-0.20	-0.17	-0.17	-0.15	0.18	0.15	0.29	0.36	1.00	-	-	-	-
PTI	-0.19	-0.10	-0.18	-0.19	-0.20	-0.19	-0.17	-0.17	-0.15	0.13	0.14	0.19	0.21	0.94	1.00	-	-	-
λ Skew	-0.08	-0.06	-0.08	-0.08	-0.08	-0.08	-0.07	-0.07	-0.07	0.10	0.11	0.08	0.09	0.74	0.83	1.00	-	-
λ Var	-0.17	-0.10	-0.17	-0.18	-0.18	-0.18	-0.15	-0.15	-0.15	0.11	0.12	0.10	0.11	0.85	0.96	0.91	1.00	-
TTI	-0.20	-0.06	-0.19	-0.21	-0.21	-0.20	-0.18	-0.18	-0.18	0.10	0.13	0.10	0.08	0.76	0.92	0.71	0.89	1.00

Table A-81: Performance Measures Correlation Matrix (2011) - All (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.69	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.71	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.71	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.72	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.75	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.77	0.99	0.98	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.94	0.79	0.98	0.96	0.96	0.97	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.38	0.62	0.49	0.41	0.42	0.45	0.56	0.59	0.64	1.00	-	-	-	-	-	-	-	-
TTV_85	0.39	0.59	0.49	0.42	0.42	0.45	0.57	0.60	0.64	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.34	0.63	0.44	0.36	0.37	0.39	0.51	0.54	0.61	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.28	0.60	0.38	0.31	0.31	0.34	0.45	0.49	0.56	0.94	0.90	0.99	1.00	-	-	-	-	-
BTI	-0.31	-0.10	-0.27	-0.31	-0.31	-0.30	-0.24	-0.21	-0.17	0.27	0.24	0.33	0.35	1.00	-	-	-	-
PTI	-0.13	-0.05	-0.12	-0.13	-0.13	-0.13	-0.10	-0.09	-0.08	0.10	0.09	0.11	0.13	0.37	1.00	-	-	-
λ Skew	-0.07	0.14	-0.04	-0.08	-0.08	-0.08	0.00	0.03	0.06	0.43	0.39	0.44	0.47	0.53	0.19	1.00	-	-
λ Var	-0.28	-0.09	-0.25	-0.29	-0.29	-0.27	-0.20	-0.17	-0.14	0.36	0.35	0.35	0.36	0.89	0.38	0.61	1.00	-
TTI	-0.07	-0.04	-0.07	-0.08	-0.08	-0.08	-0.06	-0.06	-0.06	0.03	0.03	0.03	0.04	0.16	0.97	0.06	0.19	1.00

Table A-82: Performance Measures Correlation Matrix (2011) - All (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.81	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.83	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.83	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.84	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.84	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.85	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.85	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.55	0.63	0.65	0.59	0.60	0.65	0.68	0.69	0.71	1.00	-	-	-	-	-	-	-	-
TTV_85	0.55	0.61	0.65	0.59	0.60	0.65	0.68	0.69	0.71	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.52	0.63	0.62	0.56	0.57	0.62	0.65	0.67	0.69	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.47	0.60	0.56	0.51	0.52	0.56	0.60	0.61	0.64	0.93	0.89	0.98	1.00	-	-	-	-	-
BTI	-0.20	-0.18	-0.18	-0.19	-0.19	-0.18	-0.17	-0.17	-0.16	-0.01	-0.01	0.01	0.03	1.00	-	-	-	-
PTI	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12	-0.02	-0.02	-0.01	0.00	0.17	1.00	-	-	-
λ Skew	-0.10	-0.09	-0.10	-0.10	-0.10	-0.10	-0.09	-0.08	-0.08	0.01	0.00	0.03	0.06	0.20	0.11	1.00	-	-
λ Var	-0.32	-0.30	-0.30	-0.33	-0.33	-0.30	-0.29	-0.28	-0.27	0.08	0.08	0.08	0.07	0.46	0.33	0.47	1.00	-
TTI	-0.07	-0.07	-0.08	-0.08	-0.08	-0.08	-0.07	-0.07	-0.07	-0.02	-0.01	-0.02	-0.01	0.05	0.98	0.03	0.19	1.00

Table A-83: Performance Measures Correlation Matrix (2011) - All (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.66	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.68	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.68	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.71	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.95	0.76	0.99	0.97	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.94	0.77	0.99	0.96	0.96	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.91	0.80	0.97	0.93	0.93	0.95	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.31	0.64	0.46	0.34	0.35	0.42	0.56	0.60	0.66	1.00	-	-	-	-	-	-	-	-
TTV_85	0.32	0.61	0.47	0.35	0.35	0.43	0.57	0.60	0.65	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.27	0.64	0.42	0.30	0.30	0.37	0.51	0.56	0.63	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.23	0.62	0.37	0.26	0.26	0.32	0.47	0.51	0.59	0.95	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.17	0.00	-0.12	-0.15	-0.15	-0.14	-0.10	-0.08	-0.05	0.17	0.15	0.20	0.22	1.00	-	-	-	-
PTI	-0.12	0.01	-0.09	-0.12	-0.12	-0.10	-0.06	-0.05	-0.02	0.18	0.16	0.19	0.21	0.20	1.00	-	-	-
λ Skew	-0.08	0.11	-0.06	-0.08	-0.08	-0.08	-0.03	-0.01	0.03	0.20	0.15	0.24	0.28	0.26	0.19	1.00	-	-
λ Var	-0.25	0.03	-0.18	-0.25	-0.25	-0.21	-0.12	-0.08	-0.03	0.42	0.39	0.44	0.46	0.46	0.41	0.57	1.00	-
TTI	-0.07	-0.01	-0.06	-0.07	-0.07	-0.06	-0.04	-0.04	-0.03	0.08	0.08	0.08	0.08	0.06	0.97	0.06	0.20	1.00

Table A-84: Performance Measures Correlation Matrix (2011) - All (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.77	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.79	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.79	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.79	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.80	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.80	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.56	0.56	0.62	0.59	0.59	0.62	0.63	0.65	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.54	0.54	0.59	0.56	0.56	0.60	0.61	0.61	0.62	0.91	1.00	-	-	-	-	-	-	-
TTV_95	0.53	0.54	0.59	0.56	0.56	0.58	0.60	0.61	0.63	0.95	0.89	1.00	-	-	-	-	-	-
BT	0.44	0.47	0.50	0.48	0.48	0.49	0.51	0.53	0.55	0.86	0.71	0.94	1.00	-	-	-	-	-
BTI	-0.21	-0.14	-0.18	-0.20	-0.20	-0.18	-0.17	-0.17	-0.16	0.21	0.24	0.23	0.18	1.00	-	-	-	-
PTI	-0.05	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.00	0.00	0.00	0.01	0.15	1.00	-	-	-
λ Skew	-0.06	-0.03	-0.05	-0.05	-0.05	-0.06	-0.05	-0.04	-0.04	0.12	0.09	0.11	0.17	0.35	0.07	1.00	-	-
λ Var	-0.22	-0.14	-0.19	-0.22	-0.22	-0.19	-0.18	-0.18	-0.18	0.26	0.32	0.23	0.12	0.79	0.18	0.54	1.00	-
TTI	-0.04	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.01	0.00	-0.01	-0.01	0.09	1.00	0.03	0.14	1.00

Table A-85: Performance Measures Correlation Matrix (2012) - Monday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.80	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.73	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.73	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.77	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.94	0.85	0.99	0.96	0.96	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.92	0.87	0.98	0.94	0.94	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.88	0.90	0.95	0.90	0.90	0.92	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.27	0.73	0.41	0.28	0.28	0.35	0.54	0.59	0.66	1.00	-	-	-	-	-	-	-	-
TTV_85	0.26	0.71	0.41	0.27	0.28	0.35	0.54	0.58	0.65	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.25	0.73	0.39	0.26	0.26	0.32	0.52	0.57	0.65	0.99	0.97	1.00	-	-	-	-	-	-
BT	0.23	0.71	0.36	0.24	0.24	0.29	0.49	0.55	0.63	0.97	0.94	0.99	1.00	-	-	-	-	-
BTI	-0.21	0.11	-0.14	-0.21	-0.21	-0.19	-0.07	-0.03	0.04	0.42	0.40	0.45	0.48	1.00	-	-	-	-
PTI	-0.20	0.12	-0.13	-0.21	-0.21	-0.17	-0.04	0.00	0.06	0.48	0.48	0.49	0.49	0.91	1.00	-	-	-
λ Skew	0.24	0.16	0.22	0.22	0.22	0.21	0.21	0.22	0.21	0.09	0.07	0.09	0.09	0.06	0.05	1.00	-	-
λ Var	-0.17	0.01	-0.12	-0.17	-0.17	-0.13	-0.07	-0.05	-0.02	0.28	0.29	0.26	0.24	0.26	0.40	0.03	1.00	-
TTI	-0.22	0.09	-0.15	-0.22	-0.22	-0.18	-0.07	-0.03	0.02	0.43	0.45	0.43	0.42	0.79	0.93	0.02	0.29	1.00

Table A-86: Performance Measures Correlation Matrix (2012) - Monday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.87	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.89	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.89	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.91	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.92	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.93	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.94	0.99	0.98	0.98	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.38	0.67	0.49	0.43	0.44	0.48	0.54	0.56	0.59	1.00	-	-	-	-	-	-	-	-
TTV_85	0.37	0.65	0.48	0.42	0.43	0.47	0.53	0.55	0.58	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.35	0.66	0.46	0.40	0.40	0.45	0.50	0.53	0.56	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.32	0.63	0.42	0.36	0.37	0.41	0.47	0.49	0.53	0.96	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.26	-0.14	-0.24	-0.26	-0.26	-0.25	-0.23	-0.21	-0.19	0.14	0.11	0.19	0.24	1.00	-	-	-	-
PTI	-0.29	-0.19	-0.28	-0.29	-0.29	-0.28	-0.26	-0.25	-0.23	0.11	0.10	0.15	0.18	0.94	1.00	-	-	-
λ Skew	-0.11	-0.02	-0.10	-0.11	-0.11	-0.11	-0.08	-0.07	-0.06	0.16	0.13	0.18	0.22	0.68	0.60	1.00	-	-
λ Var	-0.17	-0.11	-0.14	-0.17	-0.17	-0.13	-0.13	-0.12	-0.12	0.19	0.24	0.16	0.10	0.03	0.18	0.18	1.00	-
TTI	-0.28	-0.21	-0.27	-0.28	-0.29	-0.28	-0.26	-0.25	-0.24	0.06	0.06	0.08	0.11	0.76	0.91	0.38	0.04	1.00

Table A-87: Performance Measures Correlation Matrix (2012) - Monday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.69	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.80	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.72	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.73	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.77	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.92	0.84	0.99	0.94	0.95	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.90	0.86	0.97	0.92	0.93	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.86	0.89	0.95	0.88	0.89	0.93	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.18	0.64	0.39	0.22	0.23	0.35	0.53	0.58	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.19	0.61	0.39	0.22	0.24	0.35	0.54	0.58	0.62	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.18	0.67	0.38	0.22	0.23	0.33	0.50	0.56	0.65	0.95	0.91	1.00	-	-	-	-	-	-
BT	0.16	0.65	0.35	0.19	0.21	0.30	0.46	0.53	0.63	0.91	0.85	0.99	1.00	-	-	-	-	-
BTI	-0.18	0.18	-0.09	-0.17	-0.17	-0.13	-0.03	0.02	0.12	0.42	0.34	0.54	0.59	1.00	-	-	-	-
PTI	-0.18	0.21	-0.07	-0.18	-0.17	-0.11	0.02	0.07	0.17	0.55	0.49	0.64	0.67	0.93	1.00	-	-	-
λ Skew	0.14	0.12	0.13	0.13	0.13	0.12	0.12	0.14	0.15	0.06	0.03	0.11	0.13	0.17	0.14	1.00	-	-
λ Var	-0.16	0.03	-0.09	-0.15	-0.15	-0.10	-0.04	-0.02	0.01	0.26	0.26	0.27	0.25	0.20	0.31	0.04	1.00	-
TTI	-0.20	0.18	-0.09	-0.20	-0.19	-0.12	0.02	0.06	0.12	0.57	0.56	0.58	0.57	0.76	0.90	0.07	0.18	1.00

Table A-88: Performance Measures Correlation Matrix (2012) - Monday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.92	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.60	0.66	0.64	0.62	0.62	0.65	0.66	0.67	0.67	1.00	-	-	-	-	-	-	-	-
TTV_85	0.56	0.62	0.61	0.59	0.58	0.62	0.63	0.63	0.63	0.86	1.00	-	-	-	-	-	-	-
TTV_95	0.54	0.65	0.60	0.57	0.57	0.60	0.61	0.63	0.63	0.95	0.84	1.00	-	-	-	-	-	-
BT	0.43	0.57	0.48	0.47	0.47	0.48	0.49	0.51	0.53	0.83	0.58	0.92	1.00	-	-	-	-	-
BTI	-0.10	-0.05	-0.10	-0.09	-0.09	-0.11	-0.11	-0.10	-0.09	-0.16	-0.34	-0.08	0.15	1.00	-	-	-	-
PTI	-0.24	-0.19	-0.24	-0.24	-0.24	-0.25	-0.24	-0.24	-0.23	-0.13	-0.23	-0.07	0.07	0.83	1.00	-	-	-
λ Skew	0.01	0.06	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.08	0.00	0.12	0.19	0.11	0.06	1.00	-	-
λ Var	-0.10	-0.07	-0.08	-0.10	-0.10	-0.07	-0.07	-0.06	-0.06	0.36	0.44	0.35	0.20	-0.70	-0.39	0.00	1.00	-
TTI	-0.22	-0.22	-0.23	-0.22	-0.23	-0.23	-0.23	-0.23	-0.23	-0.24	-0.24	-0.23	-0.18	0.58	0.88	-0.03	-0.43	1.00

Table A-89: Performance Measures Correlation Matrix (2012) - Wednesday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.64	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.72	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.66	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.67	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.69	1.00	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.96	0.74	0.99	0.97	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.94	0.77	0.99	0.96	0.96	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.91	0.81	0.96	0.92	0.93	0.95	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.29	0.64	0.43	0.31	0.32	0.39	0.53	0.57	0.64	1.00	-	-	-	-	-	-	-	-
TTV_85	0.27	0.59	0.41	0.29	0.30	0.37	0.52	0.55	0.61	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.26	0.68	0.40	0.29	0.29	0.35	0.49	0.55	0.63	0.97	0.93	1.00	-	-	-	-	-	-
BT	0.24	0.67	0.37	0.26	0.27	0.32	0.46	0.51	0.61	0.94	0.88	0.99	1.00	-	-	-	-	-
BTI	-0.22	0.08	-0.16	-0.22	-0.21	-0.20	-0.10	-0.06	0.00	0.40	0.37	0.44	0.46	1.00	-	-	-	-
PTI	-0.22	0.07	-0.16	-0.23	-0.22	-0.19	-0.09	-0.06	0.00	0.45	0.46	0.46	0.46	0.94	1.00	-	-	-
λ Skew	0.05	0.14	0.05	0.04	0.04	0.04	0.07	0.09	0.12	0.17	0.13	0.21	0.24	0.32	0.30	1.00	-	-
λ Var	-0.17	0.00	-0.13	-0.18	-0.17	-0.13	-0.08	-0.06	-0.04	0.29	0.31	0.26	0.24	0.27	0.41	0.15	1.00	-
TTI	-0.23	0.04	-0.17	-0.24	-0.24	-0.20	-0.10	-0.07	-0.03	0.44	0.47	0.41	0.40	0.81	0.93	0.19	0.29	1.00

Table A-90: Performance Measures Correlation Matrix (2012) - Wednesday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.85	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.87	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.87	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.88	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.90	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.91	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.91	0.99	0.98	0.98	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.40	0.66	0.52	0.45	0.46	0.51	0.56	0.58	0.62	1.00	-	-	-	-	-	-	-	-
TTV_85	0.39	0.63	0.50	0.43	0.44	0.49	0.55	0.56	0.59	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.38	0.64	0.49	0.43	0.44	0.48	0.54	0.56	0.60	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.34	0.61	0.45	0.39	0.40	0.44	0.50	0.52	0.56	0.96	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.26	-0.15	-0.24	-0.26	-0.25	-0.25	-0.22	-0.21	-0.19	0.12	0.09	0.18	0.23	1.00	-	-	-	-
PTI	-0.30	-0.21	-0.28	-0.30	-0.30	-0.29	-0.27	-0.26	-0.24	0.09	0.08	0.13	0.16	0.93	1.00	-	-	-
λ Skew	-0.07	0.04	-0.05	-0.06	-0.06	-0.06	-0.03	-0.02	-0.01	0.18	0.17	0.21	0.25	0.66	0.56	1.00	-	-
λ Var	-0.18	-0.11	-0.15	-0.17	-0.17	-0.14	-0.13	-0.12	-0.12	0.20	0.25	0.17	0.11	0.03	0.18	0.17	1.00	-
TTI	-0.29	-0.22	-0.28	-0.29	-0.29	-0.29	-0.27	-0.26	-0.25	0.03	0.03	0.05	0.07	0.71	0.89	0.33	0.05	1.00

Table A-91: Performance Measures Correlation Matrix (2012) - Wednesday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.66	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.93	0.80	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.97	0.72	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.96	0.73	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.94	0.78	1.00	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.88	0.84	0.98	0.93	0.94	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.86	0.86	0.98	0.92	0.92	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.82	0.88	0.95	0.88	0.89	0.93	0.98	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.20	0.68	0.45	0.28	0.29	0.41	0.60	0.64	0.69	1.00	-	-	-	-	-	-	-	-
TTV_85	0.20	0.66	0.46	0.28	0.30	0.42	0.60	0.63	0.68	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.20	0.70	0.44	0.27	0.29	0.40	0.58	0.63	0.70	0.98	0.96	1.00	-	-	-	-	-	-
BT	0.18	0.68	0.42	0.25	0.27	0.37	0.55	0.60	0.68	0.96	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.17	0.16	-0.06	-0.15	-0.14	-0.10	0.02	0.06	0.13	0.44	0.38	0.49	0.54	1.00	-	-	-	-
PTI	-0.18	0.17	-0.06	-0.16	-0.16	-0.10	0.04	0.08	0.15	0.52	0.48	0.55	0.58	0.94	1.00	-	-	-
λ Skew	0.02	0.28	0.08	0.04	0.04	0.05	0.13	0.16	0.21	0.32	0.27	0.38	0.42	0.69	0.58	1.00	-	-
λ Var	-0.15	0.03	-0.08	-0.14	-0.14	-0.09	-0.02	0.00	0.03	0.28	0.27	0.28	0.26	0.22	0.34	0.25	1.00	-
TTI	-0.22	0.15	-0.09	-0.20	-0.19	-0.12	0.02	0.06	0.11	0.52	0.50	0.53	0.54	0.80	0.92	0.42	0.22	1.00

Table A-92: Performance Measures Correlation Matrix (2012) - Wednesday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.92	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.92	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.67	0.71	0.72	0.69	0.69	0.73	0.73	0.73	0.73	1.00	-	-	-	-	-	-	-	-
TTV_85	0.56	0.60	0.61	0.58	0.58	0.62	0.62	0.62	0.62	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.59	0.69	0.64	0.62	0.62	0.65	0.66	0.66	0.67	0.93	0.92	1.00	-	-	-	-	-	-
BT	0.50	0.65	0.56	0.54	0.54	0.56	0.57	0.57	0.59	0.77	0.67	0.90	1.00	-	-	-	-	-
BTI	-0.08	-0.03	-0.08	-0.07	-0.07	-0.10	-0.09	-0.09	-0.08	-0.31	-0.38	-0.21	0.01	1.00	-	-	-	-
PTI	-0.21	-0.16	-0.21	-0.20	-0.21	-0.22	-0.21	-0.21	-0.21	-0.23	-0.24	-0.15	-0.04	0.80	1.00	-	-	-
λ Skew	0.02	0.06	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.09	0.17	0.09	0.04	1.00	-	-
λ Var	-0.12	-0.08	-0.09	-0.12	-0.12	-0.08	-0.08	-0.08	-0.08	0.40	0.47	0.39	0.24	-0.74	-0.40	-0.01	1.00	-
TTI	-0.18	-0.17	-0.19	-0.18	-0.18	-0.19	-0.19	-0.19	-0.19	-0.26	-0.23	-0.24	-0.22	0.57	0.90	-0.03	-0.40	1.00

Table A-93: Performance Measures Correlation Matrix (2012) - Friday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.63	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.67	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.64	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.64	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.65	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.66	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.66	0.99	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.68	0.99	0.98	0.98	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.41	0.44	0.50	0.43	0.44	0.48	0.55	0.58	0.61	1.00	-	-	-	-	-	-	-	-
TTV_85	0.42	0.43	0.51	0.45	0.45	0.49	0.57	0.59	0.61	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.39	0.50	0.48	0.42	0.42	0.46	0.53	0.56	0.60	0.96	0.93	1.00	-	-	-	-	-	-
BT	0.34	0.40	0.43	0.37	0.38	0.41	0.48	0.51	0.56	0.94	0.89	0.98	1.00	-	-	-	-	-
BTI	-0.24	-0.11	-0.23	-0.24	-0.24	-0.24	-0.21	-0.19	-0.17	0.15	0.11	0.20	0.26	1.00	-	-	-	-
PTI	-0.25	-0.12	-0.25	-0.26	-0.26	-0.26	-0.23	-0.22	-0.20	0.10	0.09	0.14	0.17	0.94	1.00	-	-	-
λ Skew	0.16	0.07	0.14	0.14	0.14	0.13	0.13	0.14	0.14	0.05	0.02	0.08	0.10	0.11	0.11	1.00	-	-
λ Var	-0.16	-0.08	-0.14	-0.17	-0.17	-0.14	-0.12	-0.12	-0.11	0.19	0.22	0.16	0.11	0.15	0.30	0.04	1.00	-
TTI	-0.26	-0.10	-0.26	-0.27	-0.28	-0.27	-0.24	-0.24	-0.22	0.07	0.07	0.09	0.10	0.77	0.90	0.06	0.17	1.00

Table A-94: Performance Measures Correlation Matrix (2012) - Friday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.85	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.88	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.90	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.91	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.92	1.00	0.99	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.95	0.93	0.99	0.98	0.98	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.33	0.62	0.46	0.39	0.40	0.45	0.52	0.54	0.57	1.00	-	-	-	-	-	-	-	-
TTV_85	0.29	0.58	0.43	0.36	0.37	0.42	0.49	0.51	0.54	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.63	0.47	0.40	0.41	0.45	0.52	0.54	0.58	0.97	0.95	1.00	-	-	-	-	-	-
BT	0.32	0.62	0.45	0.39	0.40	0.44	0.50	0.53	0.57	0.95	0.91	0.99	1.00	-	-	-	-	-
BTI	-0.27	-0.14	-0.24	-0.25	-0.25	-0.25	-0.22	-0.20	-0.18	0.16	0.13	0.20	0.24	1.00	-	-	-	-
PTI	-0.30	-0.19	-0.27	-0.29	-0.29	-0.28	-0.26	-0.24	-0.22	0.12	0.11	0.14	0.16	0.93	1.00	-	-	-
λ Skew	0.14	0.07	0.12	0.13	0.13	0.12	0.12	0.12	0.11	0.01	-0.01	0.01	0.02	0.09	0.08	1.00	-	-
λ Var	-0.17	-0.11	-0.14	-0.17	-0.17	-0.14	-0.13	-0.12	-0.12	0.19	0.23	0.15	0.10	0.04	0.19	0.02	1.00	-
TTI	-0.29	-0.21	-0.28	-0.29	-0.29	-0.28	-0.26	-0.25	-0.24	0.07	0.07	0.08	0.09	0.75	0.91	0.03	0.06	1.00

Table A-95: Performance Measures Correlation Matrix (2012) - Friday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.64	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.95	0.76	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.67	0.97	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.69	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.95	0.73	1.00	0.98	0.98	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.88	0.80	0.98	0.91	0.92	0.97	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.86	0.81	0.97	0.89	0.90	0.95	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.82	0.83	0.95	0.85	0.87	0.92	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.21	0.62	0.47	0.26	0.29	0.43	0.63	0.67	0.72	1.00	-	-	-	-	-	-	-	-
TTV_85	0.21	0.60	0.47	0.26	0.29	0.43	0.64	0.67	0.71	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.21	0.66	0.47	0.26	0.29	0.42	0.62	0.66	0.73	0.98	0.97	1.00	-	-	-	-	-	-
BT	0.20	0.65	0.45	0.25	0.28	0.39	0.60	0.64	0.71	0.96	0.93	0.99	1.00	-	-	-	-	-
BTI	-0.19	0.15	-0.08	-0.18	-0.17	-0.12	0.02	0.06	0.13	0.42	0.38	0.48	0.53	1.00	-	-	-	-
PTI	-0.19	0.18	-0.05	-0.18	-0.17	-0.10	0.08	0.12	0.19	0.55	0.53	0.60	0.63	0.92	1.00	-	-	-
λ Skew	0.00	0.25	0.06	0.01	0.01	0.01	0.11	0.14	0.19	0.28	0.24	0.35	0.40	0.69	0.58	1.00	-	-
λ Var	-0.15	0.03	-0.07	-0.14	-0.14	-0.08	0.00	0.02	0.04	0.27	0.27	0.27	0.26	0.20	0.32	0.23	1.00	-
TTI	-0.21	0.17	-0.05	-0.20	-0.18	-0.09	0.08	0.12	0.18	0.58	0.57	0.60	0.60	0.79	0.93	0.41	0.21	1.00

Table A-96: Performance Measures Correlation Matrix (2012) - Friday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.91	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.93	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	1.00	0.93	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	1.00	0.93	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.93	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.93	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.94	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.56	0.66	0.61	0.58	0.59	0.61	0.63	0.64	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.53	0.60	0.57	0.54	0.54	0.58	0.60	0.60	0.60	0.93	1.00	-	-	-	-	-	-	-
TTV_95	0.54	0.68	0.60	0.57	0.58	0.60	0.61	0.62	0.65	0.90	0.82	1.00	-	-	-	-	-	-
BT	0.46	0.60	0.51	0.49	0.50	0.51	0.53	0.54	0.57	0.78	0.63	0.95	1.00	-	-	-	-	-
BTI	-0.08	0.00	-0.08	-0.07	-0.07	-0.09	-0.08	-0.07	-0.06	-0.08	-0.20	0.04	0.22	1.00	-	-	-	-
PTI	-0.24	-0.16	-0.24	-0.23	-0.23	-0.24	-0.23	-0.23	-0.22	-0.09	-0.14	0.00	0.11	0.84	1.00	-	-	-
λ Skew	0.20	0.18	0.20	0.21	0.21	0.20	0.21	0.21	0.21	0.11	0.06	0.09	0.13	0.01	-0.03	1.00	-	-
λ Var	-0.11	-0.07	-0.08	-0.11	-0.11	-0.07	-0.07	-0.07	-0.07	0.35	0.43	0.28	0.13	-0.67	-0.38	-0.01	1.00	-
TTI	-0.24	-0.23	-0.25	-0.25	-0.25	-0.26	-0.26	-0.26	-0.26	-0.27	-0.26	-0.22	-0.15	0.59	0.87	-0.05	-0.44	1.00

Table A-97: Performance Measures Correlation Matrix (2012) - Saturday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.81	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.81	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.81	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.81	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.82	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.82	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.82	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.53	0.60	0.60	0.57	0.57	0.61	0.62	0.63	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.49	0.56	0.56	0.52	0.52	0.56	0.58	0.58	0.59	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.49	0.59	0.56	0.53	0.53	0.56	0.58	0.59	0.61	0.94	0.88	1.00	-	-	-	-	-	-
BT	0.45	0.56	0.52	0.49	0.50	0.51	0.53	0.55	0.58	0.84	0.72	0.95	1.00	-	-	-	-	-
BTI	-0.12	-0.03	-0.12	-0.11	-0.11	-0.13	-0.12	-0.11	-0.09	-0.02	-0.12	0.13	0.28	1.00	-	-	-	-
PTI	-0.22	-0.12	-0.21	-0.21	-0.21	-0.22	-0.21	-0.20	-0.19	-0.01	-0.06	0.10	0.19	0.92	1.00	-	-	-
λ Skew	0.14	0.13	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.02	0.01	0.05	0.09	0.02	-0.01	1.00	-	-
λ Var	-0.13	-0.07	-0.10	-0.13	-0.13	-0.09	-0.08	-0.08	-0.08	0.37	0.46	0.31	0.15	-0.36	-0.14	-0.01	1.00	-
TTI	-0.25	-0.19	-0.26	-0.26	-0.26	-0.27	-0.26	-0.26	-0.26	-0.18	-0.19	-0.12	-0.07	0.62	0.80	-0.05	-0.32	1.00

Table A-98: Performance Measures Correlation Matrix (2012) - Saturday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.74	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.77	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.76	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.76	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.76	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.77	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.97	0.77	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.78	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.52	0.58	0.59	0.56	0.56	0.59	0.62	0.63	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.49	0.52	0.56	0.52	0.52	0.55	0.59	0.60	0.61	0.96	1.00	-	-	-	-	-	-	-
TTV_95	0.47	0.57	0.54	0.51	0.51	0.53	0.57	0.58	0.61	0.95	0.90	1.00	-	-	-	-	-	-
BT	0.41	0.52	0.49	0.46	0.46	0.48	0.51	0.53	0.57	0.89	0.80	0.97	1.00	-	-	-	-	-
BTI	-0.11	-0.01	-0.09	-0.09	-0.09	-0.10	-0.08	-0.07	-0.04	0.15	0.06	0.28	0.40	1.00	-	-	-	-
PTI	-0.20	-0.08	-0.19	-0.20	-0.20	-0.20	-0.18	-0.17	-0.14	0.14	0.08	0.25	0.33	0.92	1.00	-	-	-
λ Skew	0.05	0.07	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.07	0.05	0.08	0.10	0.05	0.02	1.00	-	-
λ Var	-0.12	-0.07	-0.10	-0.12	-0.12	-0.09	-0.08	-0.08	-0.08	0.29	0.34	0.23	0.12	-0.34	-0.12	0.00	1.00	-
TTI	-0.23	-0.13	-0.24	-0.24	-0.24	-0.25	-0.24	-0.23	-0.22	-0.08	-0.09	-0.02	0.03	0.61	0.81	-0.02	-0.29	1.00

Table A-99: Performance Measures Correlation Matrix (2012) - Saturday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.86	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.87	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.87	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.88	1.00	0.99	0.99	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.44	0.65	0.52	0.48	0.49	0.52	0.55	0.56	0.58	1.00	-	-	-	-	-	-	-	-
TTV_85	0.40	0.59	0.47	0.43	0.43	0.47	0.50	0.51	0.52	0.95	1.00	-	-	-	-	-	-	-
TTV_95	0.40	0.65	0.48	0.44	0.44	0.47	0.50	0.51	0.55	0.95	0.89	1.00	-	-	-	-	-	-
BT	0.37	0.62	0.45	0.42	0.42	0.44	0.47	0.49	0.52	0.89	0.78	0.97	1.00	-	-	-	-	-
BTI	-0.10	0.06	-0.08	-0.08	-0.08	-0.09	-0.07	-0.06	-0.04	0.09	-0.02	0.25	0.38	1.00	-	-	-	-
PTI	-0.20	-0.04	-0.19	-0.19	-0.19	-0.20	-0.18	-0.17	-0.15	0.10	0.04	0.24	0.32	0.90	1.00	-	-	-
λ Skew	0.13	0.16	0.14	0.14	0.14	0.13	0.14	0.14	0.14	0.05	0.02	0.06	0.09	0.00	-0.04	1.00	-	-
λ Var	-0.11	-0.06	-0.08	-0.11	-0.11	-0.07	-0.07	-0.07	-0.07	0.33	0.41	0.25	0.11	-0.49	-0.25	-0.02	1.00	-
TTI	-0.22	-0.15	-0.23	-0.22	-0.22	-0.23	-0.23	-0.22	-0.21	-0.14	-0.15	-0.05	0.01	0.63	0.83	-0.07	-0.41	1.00

Table A-100: Performance Measures Correlation Matrix (2012) - Saturday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.94	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.96	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.96	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.96	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.96	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.99	0.96	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.99	0.97	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.99	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.49	0.61	0.56	0.52	0.53	0.57	0.58	0.58	0.59	1.00	-	-	-	-	-	-	-	-
TTV_85	0.38	0.48	0.45	0.41	0.41	0.46	0.47	0.47	0.47	0.92	1.00	-	-	-	-	-	-	-
TTV_95	0.44	0.62	0.52	0.49	0.49	0.53	0.54	0.54	0.55	0.92	0.90	1.00	-	-	-	-	-	-
BT	0.43	0.62	0.49	0.47	0.48	0.49	0.51	0.51	0.53	0.76	0.63	0.90	1.00	-	-	-	-	-
BTI	-0.05	0.02	-0.06	-0.04	-0.04	-0.07	-0.06	-0.06	-0.05	-0.26	-0.37	-0.13	0.14	1.00	-	-	-	-
PTI	-0.20	-0.12	-0.19	-0.18	-0.18	-0.20	-0.19	-0.19	-0.18	-0.20	-0.22	-0.07	0.10	0.87	1.00	-	-	-
λ Skew	0.17	0.16	0.16	0.17	0.17	0.16	0.16	0.17	0.17	0.05	0.03	0.12	0.21	0.05	0.01	1.00	-	-
λ Var	-0.12	-0.07	-0.08	-0.11	-0.11	-0.07	-0.07	-0.07	-0.07	0.49	0.56	0.43	0.22	-0.72	-0.52	-0.01	1.00	-
TTI	-0.18	-0.18	-0.19	-0.18	-0.18	-0.20	-0.20	-0.20	-0.20	-0.33	-0.27	-0.26	-0.21	0.59	0.83	-0.05	-0.61	1.00

Table A-101: Performance Measures Correlation Matrix (2012) - Weekday (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.79	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.76	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.76	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.77	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.96	0.81	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.95	0.83	0.99	0.98	0.98	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.93	0.85	0.98	0.96	0.96	0.97	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.35	0.68	0.47	0.39	0.40	0.44	0.54	0.58	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.35	0.66	0.47	0.39	0.40	0.44	0.54	0.58	0.62	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.33	0.69	0.44	0.36	0.37	0.40	0.50	0.55	0.61	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.29	0.66	0.40	0.33	0.33	0.36	0.46	0.51	0.58	0.95	0.91	0.99	1.00	-	-	-	-	-
BTI	-0.30	-0.12	-0.27	-0.29	-0.29	-0.29	-0.24	-0.22	-0.18	0.18	0.16	0.22	0.25	1.00	-	-	-	-
PTI	-0.29	-0.13	-0.28	-0.31	-0.31	-0.30	-0.25	-0.22	-0.19	0.21	0.21	0.23	0.25	0.86	1.00	-	-	-
λ Skew	0.02	0.05	0.02	0.02	0.02	0.01	0.03	0.04	0.04	0.09	0.08	0.10	0.11	0.15	0.17	1.00	-	-
λ Var	-0.24	-0.11	-0.22	-0.25	-0.25	-0.23	-0.19	-0.17	-0.15	0.20	0.21	0.19	0.18	0.47	0.62	0.12	1.00	-
TTI	-0.29	-0.16	-0.29	-0.32	-0.32	-0.30	-0.26	-0.24	-0.22	0.15	0.17	0.16	0.17	0.55	0.86	0.10	0.49	1.00

Table A-102: Performance Measures Correlation Matrix (2012) - Weekday (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.84	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.88	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.89	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.90	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.90	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.91	0.99	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.50	0.68	0.61	0.56	0.57	0.61	0.64	0.66	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.50	0.67	0.62	0.56	0.57	0.61	0.65	0.66	0.68	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.46	0.69	0.57	0.52	0.53	0.57	0.61	0.62	0.65	0.96	0.94	1.00	-	-	-	-	-	-
BT	0.40	0.66	0.51	0.47	0.47	0.50	0.54	0.56	0.60	0.89	0.84	0.97	1.00	-	-	-	-	-
BTI	-0.14	-0.12	-0.14	-0.14	-0.14	-0.14	-0.13	-0.13	-0.12	-0.01	-0.02	0.02	0.04	1.00	-	-	-	-
PTI	-0.34	-0.31	-0.34	-0.35	-0.35	-0.34	-0.33	-0.32	-0.31	-0.05	-0.06	-0.01	0.02	0.37	1.00	-	-	-
λ Skew	-0.04	-0.01	-0.04	-0.04	-0.05	-0.05	-0.03	-0.03	-0.02	0.08	0.06	0.12	0.17	0.26	0.54	1.00	-	-
λ Var	-0.24	-0.21	-0.23	-0.25	-0.25	-0.23	-0.22	-0.21	-0.21	0.05	0.06	0.05	0.04	0.16	0.48	0.35	1.00	-
TTI	-0.26	-0.27	-0.27	-0.28	-0.28	-0.27	-0.27	-0.26	-0.26	-0.05	-0.04	-0.04	-0.04	0.20	0.81	0.23	0.32	1.00

Table A-103: Performance Measures Correlation Matrix (2012) - Weekday (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.81	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.97	0.76	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.97	0.77	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.96	0.79	1.00	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.93	0.83	0.99	0.97	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.91	0.84	0.98	0.95	0.95	0.97	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.88	0.86	0.96	0.92	0.93	0.95	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.25	0.59	0.42	0.30	0.31	0.38	0.53	0.58	0.64	1.00	-	-	-	-	-	-	-	-
TTV_85	0.25	0.59	0.43	0.31	0.32	0.39	0.54	0.58	0.64	0.99	1.00	-	-	-	-	-	-	-
TTV_95	0.24	0.61	0.41	0.29	0.30	0.36	0.51	0.56	0.64	0.98	0.97	1.00	-	-	-	-	-	-
BT	0.21	0.59	0.38	0.26	0.27	0.33	0.48	0.54	0.61	0.96	0.94	0.99	1.00	-	-	-	-	-
BTI	-0.20	-0.01	-0.14	-0.18	-0.18	-0.16	-0.09	-0.07	-0.02	0.28	0.26	0.32	0.34	1.00	-	-	-	-
PTI	-0.25	-0.04	-0.19	-0.25	-0.25	-0.22	-0.12	-0.09	-0.03	0.40	0.39	0.44	0.47	0.70	1.00	-	-	-
λ Skew	0.06	0.10	0.07	0.06	0.06	0.06	0.08	0.09	0.10	0.13	0.11	0.14	0.16	0.19	0.22	1.00	-	-
λ Var	-0.20	-0.05	-0.15	-0.20	-0.20	-0.17	-0.10	-0.08	-0.04	0.30	0.29	0.30	0.30	0.35	0.56	0.14	1.00	-
TTI	-0.25	-0.10	-0.22	-0.27	-0.27	-0.24	-0.16	-0.14	-0.10	0.30	0.30	0.31	0.31	0.49	0.85	0.12	0.43	1.00

Table A-104: Performance Measures Correlation Matrix (2012) - Weekday (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.82	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.88	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.96	0.88	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.96	0.88	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.96	0.88	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.51	0.64	0.61	0.58	0.59	0.62	0.63	0.63	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.47	0.60	0.56	0.54	0.54	0.57	0.58	0.58	0.58	0.88	1.00	-	-	-	-	-	-	-
TTV_95	0.49	0.65	0.58	0.56	0.56	0.59	0.60	0.60	0.61	0.88	0.92	1.00	-	-	-	-	-	-
BT	0.42	0.60	0.51	0.49	0.50	0.51	0.52	0.53	0.54	0.79	0.73	0.93	1.00	-	-	-	-	-
BTI	-0.18	-0.11	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.13	-0.07	-0.10	-0.04	0.05	1.00	-	-	-	-
PTI	-0.28	-0.23	-0.29	-0.29	-0.29	-0.29	-0.29	-0.28	-0.28	-0.06	-0.04	0.00	0.03	0.30	1.00	-	-	-
λ Skew	0.08	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.09	0.03	0.03	0.07	0.14	0.01	-0.02	1.00	-	-
λ Var	-0.11	-0.09	-0.10	-0.12	-0.12	-0.10	-0.10	-0.10	-0.10	0.23	0.28	0.21	0.12	-0.18	-0.07	-0.01	1.00	-
TTI	-0.15	-0.17	-0.19	-0.19	-0.20	-0.19	-0.19	-0.19	-0.19	-0.07	-0.02	-0.05	-0.09	-0.21	0.82	-0.04	-0.07	1.00

Table A-105: Performance Measures Correlation Matrix (2012) - Weekend (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.92	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.93	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.93	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.55	0.64	0.62	0.59	0.60	0.63	0.64	0.65	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.52	0.59	0.59	0.56	0.56	0.59	0.61	0.61	0.61	0.90	1.00	-	-	-	-	-	-	-
TTV_95	0.60	0.70	0.67	0.64	0.64	0.66	0.68	0.69	0.69	0.89	0.91	1.00	-	-	-	-	-	-
BT	0.58	0.68	0.64	0.62	0.63	0.64	0.66	0.66	0.67	0.79	0.74	0.94	1.00	-	-	-	-	-
BTI	-0.11	-0.07	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.08	-0.04	-0.06	-0.03	0.02	1.00	-	-	-	-
PTI	-0.26	-0.22	-0.26	-0.26	-0.26	-0.26	-0.25	-0.25	-0.25	-0.04	-0.03	-0.01	0.01	0.25	1.00	-	-	-
λ Skew	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.02	0.02	0.05	0.10	0.01	0.00	1.00	-	-
λ Var	-0.12	-0.09	-0.10	-0.12	-0.12	-0.10	-0.10	-0.10	-0.10	0.20	0.23	0.18	0.08	-0.09	0.00	-0.01	1.00	-
TTI	-0.19	-0.19	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.05	-0.01	-0.05	-0.09	-0.15	0.85	-0.03	-0.05	1.00

Table A-106: Performance Measures Correlation Matrix (2012) - Weekend (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.99	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.99	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.99	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.99	0.85	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.86	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.86	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.87	1.00	0.99	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.57	0.69	0.64	0.60	0.62	0.63	0.67	0.67	0.68	1.00	-	-	-	-	-	-	-	-
TTV_85	0.57	0.67	0.64	0.61	0.61	0.63	0.67	0.67	0.68	0.94	1.00	-	-	-	-	-	-	-
TTV_95	0.55	0.70	0.61	0.58	0.59	0.60	0.64	0.64	0.66	0.91	0.91	1.00	-	-	-	-	-	-
BT	0.47	0.63	0.53	0.51	0.51	0.52	0.56	0.57	0.59	0.86	0.82	0.97	1.00	-	-	-	-	-
BTI	-0.05	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01	1.00	-	-	-	-
PTI	-0.26	-0.16	-0.25	-0.26	-0.26	-0.26	-0.24	-0.24	-0.23	0.05	0.06	0.13	0.18	0.00	1.00	-	-	-
λ Skew	0.07	0.07	0.07	0.08	0.08	0.07	0.07	0.08	0.08	0.04	0.02	0.07	0.10	0.00	0.00	1.00	-	-
λ Var	-0.14	-0.09	-0.12	-0.14	-0.14	-0.12	-0.11	-0.11	-0.11	0.18	0.20	0.16	0.09	-0.01	0.09	-0.01	1.00	-
TTI	-0.19	-0.15	-0.20	-0.21	-0.21	-0.21	-0.20	-0.20	-0.20	-0.03	0.00	-0.01	-0.01	-0.26	0.84	-0.03	0.03	1.00

Table A-107: Performance Measures Correlation Matrix (2012) - Weekend (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.90	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.90	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.90	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.90	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.90	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.91	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.97	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.54	0.67	0.61	0.58	0.59	0.61	0.63	0.64	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.56	0.66	0.63	0.60	0.60	0.62	0.65	0.66	0.66	0.92	1.00	-	-	-	-	-	-	-
TTV_95	0.53	0.70	0.60	0.58	0.58	0.60	0.62	0.63	0.65	0.90	0.90	1.00	-	-	-	-	-	-
BT	0.48	0.66	0.55	0.53	0.53	0.54	0.57	0.58	0.60	0.86	0.80	0.97	1.00	-	-	-	-	-
BTI	-0.21	-0.07	-0.18	-0.19	-0.19	-0.19	-0.18	-0.17	-0.15	0.08	0.01	0.19	0.29	1.00	-	-	-	-
PTI	-0.27	-0.17	-0.27	-0.28	-0.28	-0.27	-0.26	-0.26	-0.24	0.05	0.03	0.13	0.17	0.82	1.00	-	-	-
λ Skew	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.02	0.01	0.04	0.06	0.01	-0.03	1.00	-	-
λ Var	-0.11	-0.08	-0.10	-0.12	-0.11	-0.09	-0.09	-0.09	-0.09	0.20	0.23	0.17	0.09	-0.28	-0.04	-0.02	1.00	-
TTI	-0.24	-0.21	-0.26	-0.26	-0.27	-0.26	-0.26	-0.25	-0.25	-0.07	-0.05	-0.04	-0.04	0.46	0.85	-0.06	-0.10	1.00

Table A-108: Performance Measures Correlation Matrix (2012) - Weekend (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.98	0.92	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.92	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.92	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.92	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.98	0.92	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.98	0.93	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.98	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.53	0.62	0.61	0.57	0.59	0.60	0.63	0.63	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.53	0.58	0.58	0.56	0.56	0.58	0.61	0.61	0.61	0.90	1.00	-	-	-	-	-	-	-
TTV_95	0.56	0.67	0.62	0.60	0.60	0.62	0.65	0.65	0.66	0.89	0.93	1.00	-	-	-	-	-	-
BT	0.51	0.63	0.58	0.56	0.56	0.57	0.60	0.61	0.61	0.85	0.83	0.95	1.00	-	-	-	-	-
BTI	-0.05	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	1.00	-	-	-	-
PTI	-0.23	-0.16	-0.22	-0.22	-0.22	-0.22	-0.21	-0.21	-0.21	-0.02	-0.01	0.03	0.07	0.01	1.00	-	-	-
λ Skew	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.07	0.08	0.10	0.12	0.00	0.01	1.00	-	-
λ Var	-0.10	-0.07	-0.08	-0.10	-0.10	-0.08	-0.07	-0.07	-0.08	0.24	0.26	0.23	0.11	-0.01	-0.18	0.00	1.00	-
TTI	-0.11	-0.10	-0.13	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12	-0.05	-0.01	-0.03	-0.04	-0.36	0.83	-0.01	-0.19	1.00

Table A-109: Performance Measures Correlation Matrix (2012) - All (8 AM - 9 AM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.72	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.78	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.76	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.76	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.98	0.77	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.96	0.80	1.00	0.99	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.82	0.99	0.98	0.98	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.94	0.84	0.98	0.97	0.97	0.97	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.39	0.69	0.50	0.44	0.44	0.47	0.56	0.60	0.65	1.00	-	-	-	-	-	-	-	-
TTV_85	0.40	0.65	0.51	0.45	0.45	0.48	0.57	0.60	0.64	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.35	0.69	0.45	0.39	0.39	0.41	0.50	0.54	0.61	0.96	0.90	1.00	-	-	-	-	-	-
BT	0.30	0.66	0.40	0.34	0.35	0.37	0.45	0.50	0.57	0.94	0.86	0.99	1.00	-	-	-	-	-
BTI	-0.31	-0.12	-0.28	-0.31	-0.31	-0.30	-0.26	-0.23	-0.19	0.19	0.15	0.24	0.28	1.00	-	-	-	-
PTI	-0.29	-0.14	-0.28	-0.31	-0.31	-0.30	-0.26	-0.23	-0.20	0.19	0.17	0.23	0.26	0.93	1.00	-	-	-
λ Skew	-0.09	0.09	-0.08	-0.10	-0.10	-0.11	-0.05	-0.02	0.01	0.34	0.30	0.37	0.40	0.64	0.66	1.00	-	-
λ Var	-0.23	-0.11	-0.21	-0.24	-0.24	-0.22	-0.19	-0.17	-0.15	0.18	0.19	0.17	0.17	0.47	0.57	0.45	1.00	-
TTI	-0.30	-0.18	-0.31	-0.33	-0.33	-0.32	-0.28	-0.26	-0.24	0.13	0.13	0.15	0.16	0.70	0.88	0.49	0.45	1.00

Table A-110: Performance Measures Correlation Matrix (2012) - All (12 PM - 1 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.81	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.97	0.86	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.98	0.85	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.98	0.85	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.97	0.85	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.97	0.86	1.00	0.99	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.86	1.00	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.87	1.00	0.99	0.99	0.99	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.52	0.64	0.62	0.57	0.58	0.63	0.66	0.67	0.69	1.00	-	-	-	-	-	-	-	-
TTV_85	0.53	0.62	0.63	0.58	0.58	0.63	0.66	0.67	0.68	0.97	1.00	-	-	-	-	-	-	-
TTV_95	0.50	0.66	0.61	0.56	0.56	0.61	0.64	0.66	0.68	0.97	0.94	1.00	-	-	-	-	-	-
BT	0.45	0.64	0.56	0.51	0.52	0.55	0.59	0.61	0.64	0.92	0.87	0.98	1.00	-	-	-	-	-
BTI	-0.10	-0.09	-0.10	-0.11	-0.11	-0.10	-0.10	-0.10	-0.09	0.00	-0.01	0.02	0.03	1.00	-	-	-	-
PTI	-0.34	-0.31	-0.34	-0.35	-0.35	-0.34	-0.33	-0.32	-0.31	-0.05	-0.06	-0.02	0.01	0.31	1.00	-	-	-
λ Skew	-0.09	-0.09	-0.10	-0.10	-0.10	-0.10	-0.10	-0.09	-0.09	-0.02	-0.04	-0.01	0.02	0.17	0.44	1.00	-	-
λ Var	-0.24	-0.21	-0.23	-0.24	-0.24	-0.22	-0.22	-0.21	-0.21	0.05	0.05	0.04	0.02	0.12	0.46	0.29	1.00	-
TTI	-0.26	-0.27	-0.28	-0.29	-0.29	-0.28	-0.27	-0.27	-0.26	-0.03	-0.03	-0.02	-0.02	0.30	0.85	0.22	0.32	1.00

Table A-111: Performance Measures Correlation Matrix (2012) - All (5 PM - 6 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.71	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.80	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.97	0.75	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.97	0.76	0.99	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.96	0.77	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.93	0.82	0.99	0.97	0.97	0.99	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.92	0.83	0.98	0.96	0.96	0.98	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.89	0.85	0.96	0.93	0.93	0.95	0.99	0.99	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.27	0.60	0.42	0.31	0.31	0.38	0.52	0.57	0.63	1.00	-	-	-	-	-	-	-	-
TTV_85	0.28	0.60	0.43	0.32	0.32	0.39	0.54	0.57	0.63	0.98	1.00	-	-	-	-	-	-	-
TTV_95	0.25	0.60	0.40	0.29	0.29	0.35	0.50	0.54	0.63	0.98	0.95	1.00	-	-	-	-	-	-
BT	0.22	0.58	0.36	0.26	0.26	0.32	0.46	0.51	0.60	0.96	0.92	0.99	1.00	-	-	-	-	-
BTI	-0.15	0.01	-0.12	-0.15	-0.15	-0.14	-0.08	-0.05	-0.01	0.27	0.24	0.31	0.33	1.00	-	-	-	-
PTI	-0.22	0.01	-0.16	-0.23	-0.23	-0.19	-0.09	-0.05	0.02	0.50	0.47	0.53	0.54	0.61	1.00	-	-	-
λ Skew	-0.06	0.09	-0.04	-0.06	-0.06	-0.06	0.00	0.03	0.07	0.27	0.23	0.31	0.34	0.39	0.51	1.00	-	-
λ Var	-0.20	-0.05	-0.16	-0.20	-0.20	-0.17	-0.11	-0.09	-0.05	0.29	0.28	0.30	0.30	0.31	0.54	0.36	1.00	-
TTI	-0.21	-0.04	-0.17	-0.24	-0.24	-0.20	-0.11	-0.08	-0.03	0.42	0.42	0.42	0.42	0.51	0.89	0.34	0.44	1.00

Table A-112: Performance Measures Correlation Matrix (2012) - All (9 PM - 10 PM)

MOE	MinTravel-Time	MaxTravel-Time	AvgTravel-Time	TT-10th Percentile	TT-15th Percentile	TT-50th Percentile	TT-85th Percentile	TT-90th Percentile	TT-95th Percentile	TTV_90	TTV_85	TTV_95	BT	BTI	PTI	λ Skew	λ Var	TTI
MinTravel_Time	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MaxTravel_Time	0.83	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AvgTravel_Time	0.96	0.89	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_10th Percentile	0.96	0.89	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_15th Percentile	0.96	0.89	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
TT_50th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
TT_85th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-
TT_90th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-
TT_95th Percentile	0.96	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
TTV_90	0.55	0.65	0.64	0.61	0.62	0.64	0.65	0.66	0.66	1.00	-	-	-	-	-	-	-	-
TTV_85	0.57	0.65	0.65	0.63	0.63	0.65	0.67	0.67	0.66	0.90	1.00	-	-	-	-	-	-	-
TTV_95	0.58	0.68	0.66	0.64	0.64	0.66	0.67	0.68	0.69	0.85	0.86	1.00	-	-	-	-	-	-
BT	0.47	0.59	0.55	0.54	0.54	0.55	0.56	0.57	0.59	0.75	0.68	0.95	1.00	-	-	-	-	-
BTI	-0.16	-0.11	-0.13	-0.12	-0.12	-0.13	-0.12	-0.12	-0.12	-0.07	-0.09	-0.05	0.01	1.00	-	-	-	-
PTI	-0.30	-0.27	-0.31	-0.31	-0.31	-0.31	-0.31	-0.31	-0.30	-0.09	-0.10	-0.05	0.01	0.23	1.00	-	-	-
λ Skew	0.04	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.08	0.08	0.10	0.00	0.00	1.00	-	-
λ Var	-0.11	-0.10	-0.11	-0.12	-0.12	-0.10	-0.10	-0.10	-0.10	0.20	0.23	0.16	0.08	-0.11	-0.04	0.00	1.00	-
TTI	-0.15	-0.19	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.10	-0.07	-0.08	-0.08	-0.33	0.77	-0.02	-0.08	1.00

COMMERCIAL REMOTE SENSING & SPATIAL INFORMATION (CRS & SI) TECHNOLOGIES PROGRAM FOR RELIABLE TRANSPORTATION SYSTEMS PLANNING: VOLUME 3 - DECISION SUPPORT TOOLS (DSTs) IMPLEMENTATION AND USER GUIDE

Final Report No. RITARS-12-H-UNCC-3

Prepared for
The Office of the Assistant Secretary for Research and Technology (OST-R)
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16. Abstract

This report presents data processing, system functionality and implementation, and user interface of decision support tools (DSTs) to 1) examine spatial variations in the condition of the transportation network based on various performance measures, 2) assess the performance of links along a selected corridor in the transportation network, 3) identify and rank top "N" unreliable links in the transportation network, 4) assess the performance of a link by time-of-the-day and day-of-the-week during a year, 5) retrieve and report performance measures for any further analysis, and, 6) evaluate the effect of an incident on nearby links in the transportation network. The four DSTs are: 1) Reliability Mapping DST; 2) "HeatChart" Visualization DST; 3) Reports DST; and 4) Effect of Incident DST. These DSTs allow practitioners to explore and report performance of links and evaluate the effect of incidents on the transportation network. The outputs from the DSTs can be used to develop performance-based congestion management plans, identification of links (to divert traffic due to an incident) for incident management and re-routing traffic over time, and to assist planners and engineers in their day-to-day activities (mobility and safety improvements). Further, the DSTs also assist transportation system users make reliable route, mode and departure time decisions. Due to the nature of analytical needs and related decisions, it is recommended that DSTs developed and discussed in this report be implemented at regional or local level.

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EXECUTIVE SUMMARY

There has been a paradigm shift in focus from intersection-level to corridor- and area-level analysis and performance measures in recent years. The possibility of capturing dynamic and continuous travel time and/or speed data by responsible governing agencies or obtaining it from private sources such as INRIX, TomTom, HERE, etc. opens many pragmatic avenues to assess reliability of transportation network and make better decisions. Travel time reliability (or index or variability) is considered as the most viable performance measure for corridor-level analysis with potential to be widely used for transportation system planning, project prioritization, and allocation of resources.

Decision support tools (DSTs) are vital to process large datasets, compute performance measures, assess spatial and temporal variations, and rank the links to effectively utilize limited transportation dollars. The outputs from the DSTs can help to develop performance-based congestion management plans, identification of links (to divert traffic due to an incident) for incident management and re-routing traffic over time (say, up to 2 hours after a fatal crash), and to assist planners and engineers in their day-to-day activities (mobility and safety improvements at link- or corridor-level). These DSTs also assist transportation network users make reliable route, mode and departure time decisions.

This report outlines the development and implementation of DSTs that would help practitioners to:

1) examine spatial variations in the condition of the transportation network based on various performance measures,
2) assess the performance of links along a selected corridor in the transportation network,
3) identify and rank top "N" unreliable links in the transportation network,
4) assess the performance of a link by time-of-the-day and day-of-the-week during a year,
5) retrieve and report performance measures data for any further analysis, and,
6) evaluate the effect of an incident on nearby links in the transportation network.

Travel time data for the Charlotte region in the state of North Carolina, for the years 2009 to 2013, comprising about 298 to 2058 links (Traffic Message Channel codes) were used in the development of DSTs. The raw data requested has average travel times for every 1-minute for the entire 5 year period.

The raw data obtained was used to compute various travel time measures. These include: 1) minimum travel time, 2) average travel time, 3) maximum travel time, 4) median travel time, 5) 85^{th} percentile travel time, and 7) 95^{th} percentile travel time (also referred to as planning time - PT). Several factors such as time-of-the-day, day-of-the-week, all weekdays of a year, all weekends of a year and all days were considered in evaluating these travel time measures. From the travel time measures, the reliability measures such as buffer time (BT), buffer time index (BTI), planning time index (PTI), travel time index (TTI), λ skew and λ variance were computed. All the processed information was stored as a single database to be retrieved by the DSTs, as needed, based on input provided by the practitioner.

Four interactive DSTs were developed as a part of this project. They are: 1) Reliability Mapping DST, 2) "HeatChart" Visualization DST, 3) Reports DST, and, 4) Effect of Incident DST. The DSTs are built with analytical and visual capabilities to assess and report condition of the transportation network as well as facilitate practitioner's need in identifying problems and

prioritizing links for improvements. Due to the nature of analytical needs and related decisions, it is recommended that DSTs developed and discussed in this report be implemented at regional or local level.

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CHAPTER 1: INTRODUCTION

Traffic congestion, in general, reduces the capacity of the roadway and makes the traffic condition unstable. Four-two percent of America's urban freeways are congested, costing the economy an estimated $101 billion in wasted time and fuel annually (ASCE, 2014). Congestion due to regular commute traffic during morning and evening peak hours is referred to as recurring congestion. It is generally measured in terms of travel time, travel time per mile, travel delay, variation in travel time or volume-to-capacity ratio, and used in long-range transportation planning decisions and project prioritization processes.

One of the major keys to reducing travel time and congestion is regular analysis of traffic flow on major traffic corridors. In conducting the analysis, performance measures are required to evaluate the consistency, dependability and reliability of the roadway for the travelling public. These metrics also help quantify intensity, duration and extent of congestion to develop performance-based congestion management plans.

Incidents during the peak hours further deteriorate operational performance on roads (lead to reduced speed and lessen freedom to maneuver). Traffic congestion due to crashes, inclement weather conditions, mechanical breakdown of vehicles, construction zones and special events is referred to as non-recurring congestion. The effect of an incident on travel time and delay varies based on the type of incident (fatal, severe injury, minor injury or PDO crash or other type of incidents), geometric conditions (number of lanes, divided or undivided road, etc.), existing traffic conditions (peak versus off-peak), the number of lanes closed, and the duration for which the segment is closed.

Commuter's reaction to traffic congestion and their acceptable norms tend to vary by the time-of-the-day (peak hour versus off-peak hour) and spatial location (downtown / uptown, urban, suburban and rural areas). As congestion increases, reliability, defined as consistency or dependability in travel times (FHWA, 2012), of travel becomes an increasingly important attribute for users of transportation network. A 1997 survey showed that travel time reliability is one of the most important factor for route choice, making it either the most or second most important reason for choosing primary commute routes (Abdelwahab and Abdel-Aty, 2001). Route-choice laboratory experiments and computer simulations conducted by Avineri and Prashker (2005) indicate that the higher the variance in travel time, the lower is travelers' sensitivity to travel time differences. In another study, results from preference data collected in Barcelona, Spain showed that travel time reliability is valued on average 2.4 times more than travel time savings (Asensio and Matas, 2008). A large proportion of the unreliability experienced by passengers can be attributed to incident related disruptions (Uniman et al., 2010).

1.1. Need for Decision Support Tools (DSTs)

There has been a paradigm shift in focus from intersection-level to corridor-level analysis and performance measures. Travel time reliability (or index or variability) is considered the most viable performance measure though agencies currently use volume-to-capacity ratio for ranking and prioritization of projects. The possibility of capturing dynamic and continuous travel time and/or speed data by responsible governing agencies or obtaining it from private sources such as INRIX, TomTom, HERE, etc. opens many pragmatic avenues to assess reliability of transportation network and would be an added asset. Several states have Strategic Transportation Planning Offices working to define thresholds (similar to level-of-service criteria) that could be

used for ranking and prioritization of corridor or regional improvement projects based on travel time reliability.

The remotely collected data from private data sources need to be archived, processed, integrated, analyzed, monitored and reported to assess reliability of transportation system through improved transportation planning methodologies. Innovative methods and usable applications with decision support tools (DSTs) will not only add value and enhance business practices adopted by state and local agencies but will also help address congestion-related transportation challenges. These DSTs are critical to develop performance-based congestion management plans and to assist planners and engineers in their day-to-day activities (mobility and safety improvements at link- or corridor-level). Questions such as what is the duration of congestion or if the link is unreliable all the time or only during selected hours of the week plagues practitioners. DSTs to visually examine link performance would help find answers to these questions.

The variation in travel time due to incidents varies by spatial location (as response times vary for downtown/uptown, urban, suburban and rural areas). It is relatively greater during off-peak hours than during peak hours. Fatal and severe injury crashes are relatively high in number during these off-peak hours (could be attributed to low traffic volume and ability to travel at higher speeds apart from other reasons). Under uncertain conditions that lead to non-recurring congestion, commuters are known to exhibit different behaviors such as risk aversion, risk neutrality and risk seeking (Yin and Idea, 2001). There are no widely accepted or commonly used measures or DSTs to assess the possible effect of non-recurring congestion on variation in travel time or traffic delay.

Congestion on a link, in particular due to an incident, could result in travel time variation on upstream or both upstream and downstream links (or vice versa) depending on whether a facility is a divided or undivided roadway. It also depends on traffic conditions and time-of-the-day. Initially after an incident, the effect of an incident on travel time variation decreases as the distance from the subject link increases. This variation could decrease at the incident location but may increase away from the location over time (queue building and dissipation patterns). Mapping and DSTs offer the potential to understand and visualize the effects both spatially and temporally, and manage the transportation network (in particular, to divert traffic on upstream and downstream links during recurring and non-recurring congestion times; re-routing through variable message signs or broadcast media). However, there are no DSTs to examine how the affects vary over time and space from the location of the incident.

Overall, there is a need for DSTs that can assist practitioners find answers to questions such as the following.

1. How does performance of links vary spatially, by the time-of-the-day, day-of-the-week, and year?
2. How could one identify unreliable links on a selected corridor in the transportation network?
3. What are the top “N” congested (unreliable) links in the transportation network for prioritization and allocation of limited resources?
4. How does the reliability of link vary by time-of-the-day and day-of-the-week during a year?
5. What is the effect of an incident on nearby links? How far does it extend and how does it vary over time?

Answers to the above questions not only help understand the effect of recurring and non-recurring congestion components on travel time and traffic delays (to identify appropriate solutions and mitigation strategies) but also serve as a platform to incorporate safety into transportation planning processes.

1.2. Project Objectives

The objectives of this report, therefore, are:

- to develop a framework for travel time data storage, retrieval, analysis and reporting to improve mobility and safety,
- to develop and implement interactive DSTs with analytical and visual capabilities to assess and report the condition of transportation network and facilitate practitioner's need in identifying and prioritizing transportation projects, and,
- to develop an interactive DST to evaluate the effect of an incident on surrounding links and facilitate practitioners need to manage transportation network by diverting or re-routing traffic through the use variable massage signs.

1.3. Organization of the Report

The remainder of this report is organized as follows. Hardware and software requirements for data processing, development of DSTs, and hosting the DSTs for access by practitioners are discussed in Chapter 2. A discussion on data processing is presented in Chapter 3. A framework of system functionality for implementation is discussed in Chapter 4. The description of how practitioners can use the DSTs to perform various analyses is presented in Chapter 5. Conclusions and directions for future research are presented in Chapter 6.

CHAPTER 2: HARDWARE AND SOFTWARE REQUIREMENTS

The configuration of the system (hardware and software) plays a major role in the ease of data processing, robustness and use of DSTs. This section briefly describes the hardware and software requirements from developer and user perspective for developing and using DSTs similar to those discussed in this report.

2.1. Developer Perspective

The hardware and software requirements for data processing and development of DSTs are described in this section.

2.1.1. Hardware Requirements

The basic system configuration used for the development of the DSTs is as follows.

- Windows Server 2012 Operating System
- System Type: 64-bit Operating System, x64-based Processor
- 3.10GHz Processor
- 8 GB 2R×8 RAM
- 4 TB 3G SATA 7.2k 3.5in MDL Hard Drive
- Raid technology & smart array controller

The system configuration was selected based on the total links in the transportation network, number of years of data, its aggregation size (1-minute, 5-minute, 10-minute, etc.), and number of DSTs being developed. Higher configuration systems may be required for faster and robust functioning of the DSTs when larger cities or more detailed data are being considered.

2.1.2. Software Requirements

Most of the software for data processing and development of DSTs require minimum hardware configuration. Based on the expertise of the developer various software are available for processing large datasets and developing DSTs. The software used for data processing and development of the DSTs in this project are summarized as follows.

- Microsoft SQL Server 2014
- Microsoft Visual Studio 2012
- SQL Server Reporting Services 2014
- Microsoft Office Suite
- Apache Tomcat 7.0
- Eclipse 1.4.0

2.2. User's Perspective

For a user to access the DSTs, a system with very minimum configuration where Java is installed to run Java based applications is required. For best results, it is recommended using Firefox or Chrome as Internet browsers. The output can be stored as Microsoft Excel spreadsheet files, in Adobe Acrobat format or as a web-based table (xml). The user should have Microsoft Office Suite and Adobe Acrobat installed to open any downloaded files.

CHAPTER 3: DATA PROCESSING

DSTs are applications based on data that assist practitioners in making decisions. Programs are written to provide practitioners with specific functions in an easy-to-use package. Visualization techniques are typically adopted, where appropriate, for easy understanding of spatial and temporal variations in travel time based performance measures.

3.1. Raw Data

Data is the backbone for the different DSTs developed as a part of this project. INRIX (INRIX, 2014) travel time data for Charlotte region in the state of North Carolina, for the years 2009 to 2013, was used in the development and illustration of working of the DSTs. The INRIX data was downloaded from RITIS website in a raw unprocessed format. The raw data file has Traffic Message Channel (TMC) code (tmc_code), time-stamp (measurement_tstamp), speed (speed), average speed (average_speed), reference speed (reference_speed), travel time (travel_time_minutes) and score (confidence_score). Each field in the raw data file is briefly described below (INRIX, 2013).

1. Traffic Message Channel (TMC) - defines section identity of the roadway segment.
2. Speed - current estimated space mean speed for the roadway segment in miles per hour.
3. Average speed - historical average mean speed for the roadway segment for that hour-of-the-day and day-of-the-week in miles per hour.
4. Reference speed - calculated “free flow” mean speed for roadway segment in miles per hour. It is the 85^{th} percentile point of the observed speeds on that segment.
5. Travel time - current estimated travel time it takes to traverse the roadway segment in minutes.
6. Score - an indicator of data type (30 indicates real-time data; 20 indicates real-time data across multiple segments; 10 indicates historical data).

The data requested has average travel times for every 1-minute for the entire 5 year period. Figure 1 shows the snapshot of the raw data downloaded from INRIX.

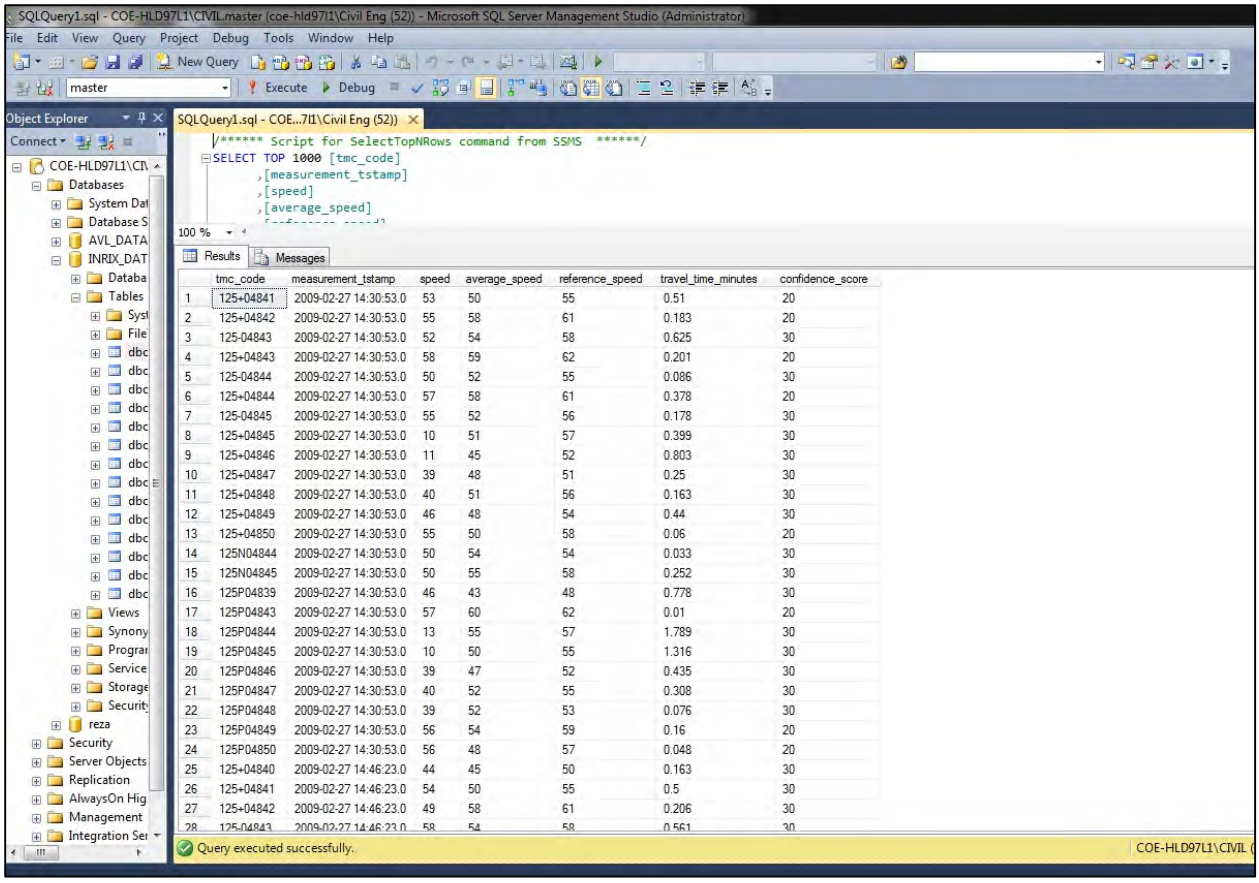

Figure 1: Snapshot of Raw Data Downloaded from INRIX

3.2. Processed Data and Final Database

The data was then processed to remove null values and other miscalculated values. The data processing and mining was performed using Microsoft SQL Server 2012. A data dictionary was developed to explain all data elements in the processed database.

As the objective of the project was to establish and develop DSTs that provide visual information of travel time and other performance measures of a given link, data tools and query applications were developed to compute various travel time measures such as 1) minimum travel time, 2) average travel time, 3) maximum travel time, 4) median travel time, 5) 85th percentile travel time, and 7) 95th percentile travel time (also referred to as planning time - PT). Several factors such as time-of-the-day, day-of-the-week, all weekdays of a year, all weekends of a year and all days were considered in evaluating these travel time measures. This database was used to compute performance measures that helps evaluate the link-level reliability. The reliability measures that were computed include buffer time (BT), buffer time index (BTI), planning time index (PTI), travel time index (TTI), λ skew and λ variance. Each of these measures are described briefly next.

1) Buffer time (BT): It is the difference of 95th percentile travel time and the average travel time. It represents the required additional time for an on time performance (Lomax et al., 2004).

Buffer time (BT) = $TT_{95} - TT_{Ave}$ Eq. 3.1

2) Buffer time index (BTI): It is the ratio of difference of 95th percentile travel time and the average travel time to the average travel time (Lomax et al., 2004).

$$\text{Buffer time index (BTI)} = \frac{TT_{95} - TT_{Avg}}{TT_{Avg}} \times 100 \quad \text{Eq. 3.2}$$

3) Planning time index (PTI): It is the ratio of 95th percentile travel time and the free flow travel time or 15th percentile time (Sisiopiku and Islam, 2012).

$$\text{Planning time index (PTI)} = \frac{TT_{95}}{TT_{free\ flow}} \quad \text{Eq. 3.3}$$

4) Travel time index (TTI): It is the ratio of average travel time to the free flow travel time (Lyman and Bertini, 2008).

$$\text{Travel time index (TTI)} = \frac{TT_{Ave}}{TT_{free\ flow}} \quad \text{Eq. 3.4}$$

5) λ skew: It is the ratio of difference in 90th percentile and 50th percentile travel times to the differences in 50th percentile and 10th percentile travel times (van Lint et al., 2004).

$$\lambda \text{ skew} = (TT_{90} - TT_{50})/(TT_{50} - TT_{10}) \quad \text{Eq. 3.5}$$

6) λ variance*:* It is the ratio of difference between 90th percentile and 10th percentile to the 50th percentile travel time (Bogers et al., 2008).

$$\lambda \text{ variance} = (TT_{90} - TT_{10})/TT_{50} \quad \text{Eq. 3.6}$$

The computed reliability measures were added to the application database so that it could be accessed by the various DSTs developed as a part of this project.

The final database has travel time and reliability measures for each link based on time-of-the-day and day-of-the-week. The database also has route or street name and TMC codes with "from-to" coordinates. Figure 2 shows the snapshot of the processed data using Microsoft SQL Server.

3.3. Data Size

Table 1 shows the number of rows and raw data size downloaded and size after processing the data for the development of DSTs. The data size increases with an increase in the number of TMC's considered and data aggregation intervals (aggregated to 15-minutes, 30-minutes, or 1-hour etc.).

Table 2 shows the comparison of reliability measures computed by aggregating 1-minute interval travel time to 30-minutes and 1-hour for 4-links on I-85 corridor. From Table 2, the minimum travel times, average travel times and 85th percentile travel times computed for two 30-minute intervals (05:00 PM - 05:30 PM and 5:30 PM - 06:00 PM) and for 1-hour interval (05:00 PM - 06:00 PM) do not vary and are almost equal. However, 95th percentile travel times and reliability measures (BTI, PTI, TTI and λ variance) are observed to be different. Therefore, at a

macro-level, travel times during an hour, average travel times and free-flow travel times do not vary and are same as the aggregate for that particular hour. However, the reliability of the links varies for every smaller interval and is different when compared to the reliability computed as an aggregate for that hour.

High processing times and low system performance was observed because of large data size in evaluating travel time measures for the transportation network at 15-minute and 30-minute intervals. Therefore, travel times measures are computed by aggregating 1-minute travel time data to every 1-hour (time-of-the-day) in this study. However, in case of the DST to evaluate the effect of an incident, a 15-minute interval data is required. Therefore, the raw data was also consolidated to every 15-minute interval along with one-hour intervals that was used for developing other DSTs.

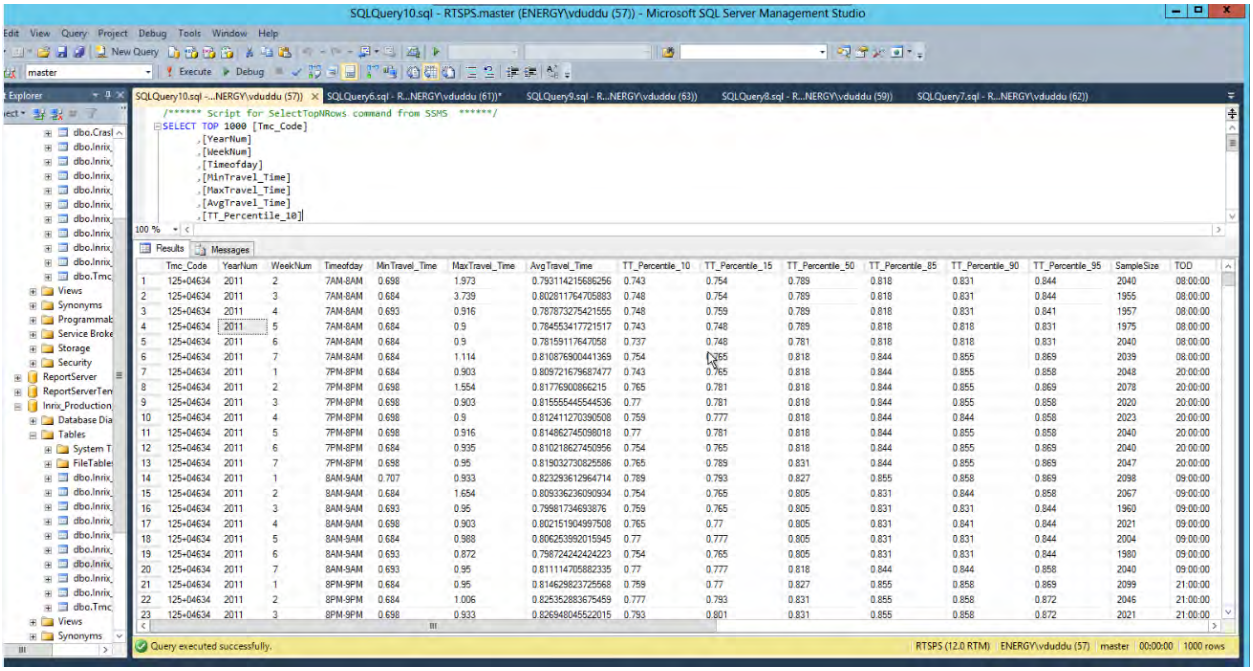

Figure 2: Snapshot of Processed Data using Microsoft SQL Server

Table 1: Summary Statistics of Raw Data Size

Year	#TMCs	# of Rows (1-minute)	#of Rows (1-hour)
2009	296	155,577,600	78,624
2010	311	163,461,600	86,184
2011	1,972	1,036,483,200	389,256
2012	1,705	896,148,000	320,712
2013	2,049	1,076,954,400	344,232

2009-2012 raw data size is equal to130GB.
2013 raw data size is equal to 65GB.

Table 2: Comparison of Travel Time Measures Computed at 30-minute and 1-hour Intervals

TMC Code	Time-of-the-Day	Travel Times							BTI	PTI	TTI	Gamma-Var
		Min	Avg	Max	15th Percentile	50th Percentile	85th Percentile	95th Percentile				
125+04642	05:00PM-05:30PM	0.31	0.37	0.58	0.34	0.36	0.39	0.41	11.49	1.20	1.08	0.17
	05:30PM-06:00PM	0.32	0.39	0.63	0.35	0.37	0.47	0.53	33.20	1.50	1.13	0.42
	05:00PM-06:00PM	0.31	0.38	0.63	0.35	0.37	0.41	0.50	31.76	1.46	1.10	0.30
125+04643	05:00PM-05:30PM	0.59	0.71	1.08	0.66	0.70	0.75	0.79	11.62	1.20	1.07	0.16
	05:30PM-06:00PM	0.62	0.74	1.19	0.68	0.71	0.80	0.92	24.25	1.35	1.09	0.28
	05:00PM-06:00PM	0.59	0.72	1.19	0.67	0.71	0.77	0.87	19.65	1.29	1.08	0.20
125+04644	05:00PM-05:30PM	0.72	0.89	7.71	0.76	0.79	0.83	0.84	-4.96	1.11	1.17	0.10
	05:30PM-06:00PM	0.72	0.91	7.71	0.77	0.81	0.83	0.86	-5.55	1.11	1.18	0.09
	05:00PM-06:00PM	0.72	0.90	7.71	0.76	0.79	0.83	0.86	-4.54	1.13	1.18	0.09
125+04645	05:00PM-05:30PM	0.79	1.09	9.90	0.85	0.90	1.01	1.80	64.83	2.12	1.29	0.34
	05:30PM-06:00PM	0.79	1.17	11.88	0.86	0.91	1.08	2.12	81.55	2.46	1.36	0.52
	05:00PM-06:00PM	0.79	1.13	11.88	0.85	0.90	1.04	1.86	64.14	2.19	1.33	0.35

Note 1: Min, Avg, Max, 15^{th} Percentile, 50^{th} Percentile, 85^{th} Percentile, and 95^{th} Percentile are minimum, average, maximum, 15^{th} percentile, 50^{th} percentile, 85^{th} percentile, and 95^{th} percentile (or PT) travel times, respectively.

Note 2: BTI, PTI and TTI are buffer time index, planning time index, and travel time index.

Note 3: Gamma-Var is λ variance.

CHAPTER 4: SYSTEM FUNCTIONALITY AND IMPLEMENTATION

To facilitate easy access and use of DSTs, this project relied on web-based data driven applications. The practitioner could use their computer or mobile device with connection to the internet and an internet browser to typically access the DSTs. The basic system functionality of the DSTs for implementation is outlined using figures 3 and 4. Figure 3 outlines the functionality of geospatial based DSTs, while Figure 4 outlines the functionality of non-geospatial based DSTs. The functionality of the DSTs involves the following steps.

1. The practitioner opens a web browser to access the DST and send a request with selected input parameters.
2. The web browser then passes on the request to a server hosted by the developer of the DST.
3. On receiving the request, the server reads the input parameters and then accesses the database developed to retrieve the data based on the selected input parameters.
4. In case of geospatial based DST (Figure 3), it sends the output from the previous step to MapQuest Server and generates a map. Connection to MapQuest Server is not needed in case of the non-geospatial based DST.
5. The web server receives the final output from MapQuest or generates the final output in case of non-geospatial based DST and sends it to the web browser.
6. The practitioner's web browser then displays the map, chart, or table and also supports other necessary interactions (example, change input parameter to re-generate outputs).

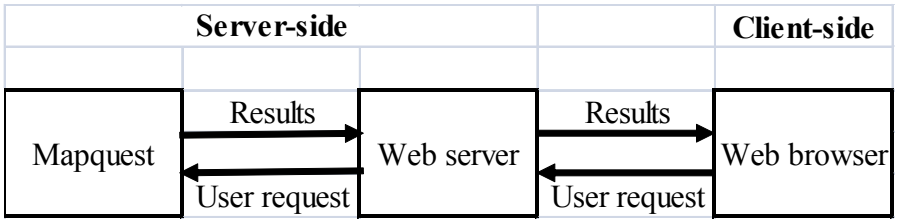

Figure 3: Flowchart Illustrating Working of Geospatial based DST

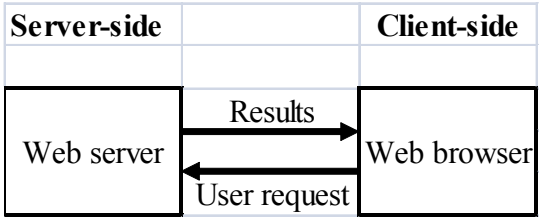

Figure 4: Flowchart Illustrating Working of Non-geospatial based DST

A detailed description of architecture for each of the four DSTs developed is described in the following sections.

4.1. Reliability Map DST

The reliability map DST uses MapQuest map to spatially represent the selected performance measure over the transportation network for the study area. This DST has been designed in a way

that is easy for the practitioner to use, understand and interact with the map. This DST retrieves data from the database and represents it over the map based on the selected input parameters. Figure 5 shows the flowchart describing the architecture of reliability mapping DST at system perspective.

The year, day-of-the-week, time-of-the day, factor (reliability performance measure) and filter (all links in the transportation network, selected route in the transportation network through the use of a dropdown menu or top 'N' unreliable links) are provided as input through the web interface. The data relevant to the selected input parameters are then retrieved from the database. The data retrieved will have all the travel time and performance measure information for each TMC code along with their respective "from-to" coordinates. This "from-to" coordinate information is used to spatially represent the output (performance measure) based on the selected input parameters on a MapQuest map. Each link (TMC code) is color coded based on their performance measure values (plus or minus 1 and 2 standard deviations from average) and is represented in the form of a legend. The information related to each TMC code is stored on the tooltip which is displayed with a red marker that is placed on each TMC code. A single click on the red marker will pop-up information on the tooltip with all the information related to the respective TMC code. To download the data displayed on the map, a click on the download button at the bottom of the page will save the data retrieved from the database into a Microsoft Excel spreadsheet. Also, a link is provided on the tooltip to view the "HeatChart". On clicking it, the visualization of performance measure by day-of-the-week and time-of-the-day based on data for the entire year for the selected TMC code is displayed.

4.2. "HeatChart" Visualization DST

The "HeatChart" visualization DST shows the selected reliability performance measure of a link as a heat chart with time-of-the-day and day-of-the-week data spanning an entire year. It can be accessed by either using the "Visualization" tab or through the tooltip information for a selected link (as mentioned in the previous section). Through visual inspection, one can identify the most unreliable day-of-the-week and time-of-the-day in a year for the selected link. The heat chart also provides an assessment of the "duration of congestion or lack of reliability". Figure 6 shows the flowchart describing the architecture of "HeatChart" visualization DST at system perspective.

The year, link (TMC code), and the factor (reliability performance measure) are provided as input parameters through the web interface. The DST checks for the validity of the input parameters. If valid, the data relevant to the selected input parameters will then be retrieved from the database. The data retrieved will have all the travel time and performance measure information for the selected TMC code. This information is represented in the form of "HeatChart".

The heat chart consists of seven concentric circles each representing a day-of-the-week. These concentric circles are further divided into 24 parts radially from the center, each representing time-of-the-day (hour). Each block of the heat chart is color coded based on data for the entire year. The higher reliability values are represented with lighter color, while dark color blocks indicate highly unreliable times of the day during a day-of-the-week. When the mouse is hovered over a block (representing a particular time-of-the-day and day-of-the-week) on the heat chart, the respective reliability performance measure for the hovered block is displayed.

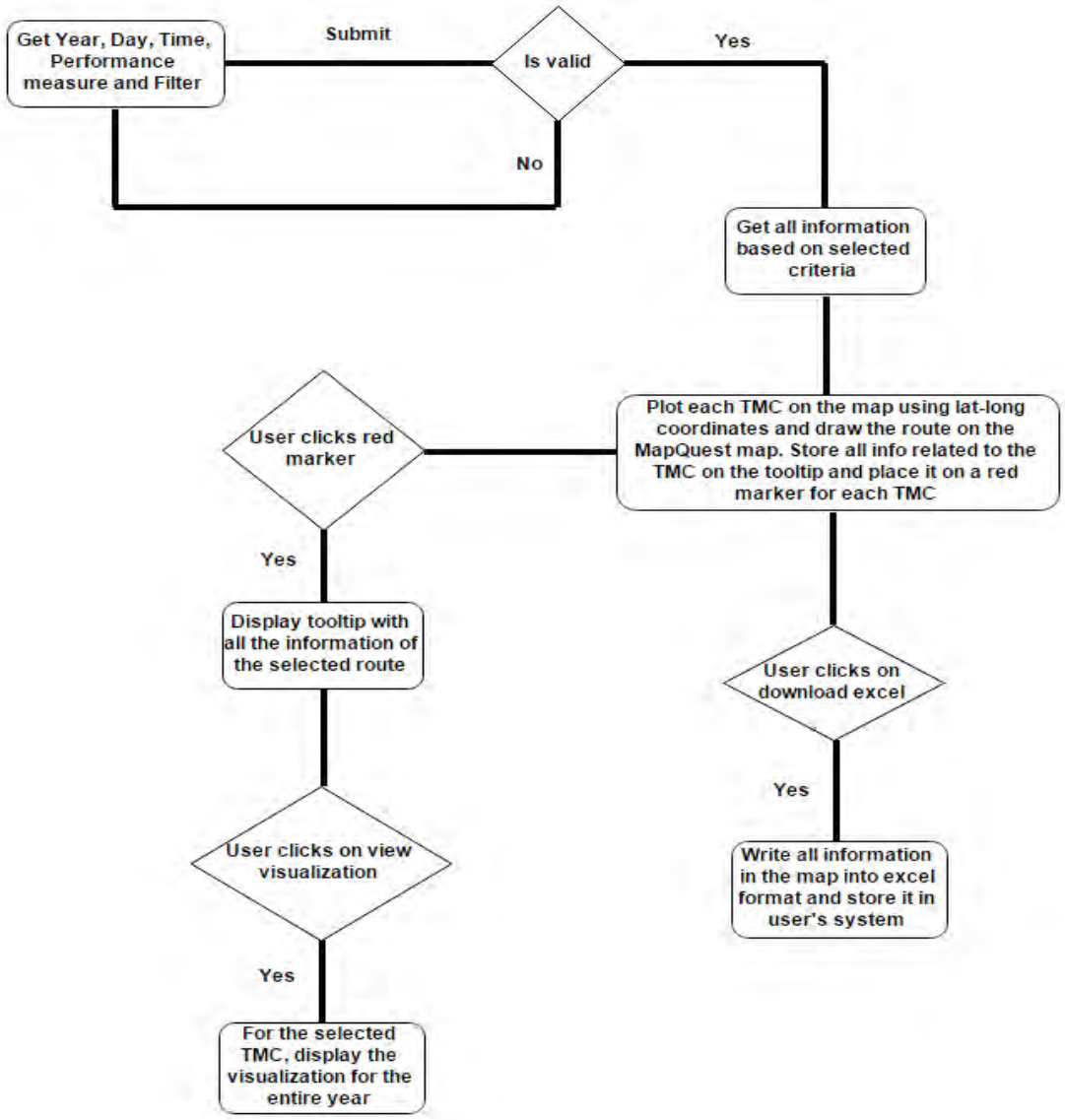

Figure 5: Architecture of Reliability Mapping DST from System Perspective

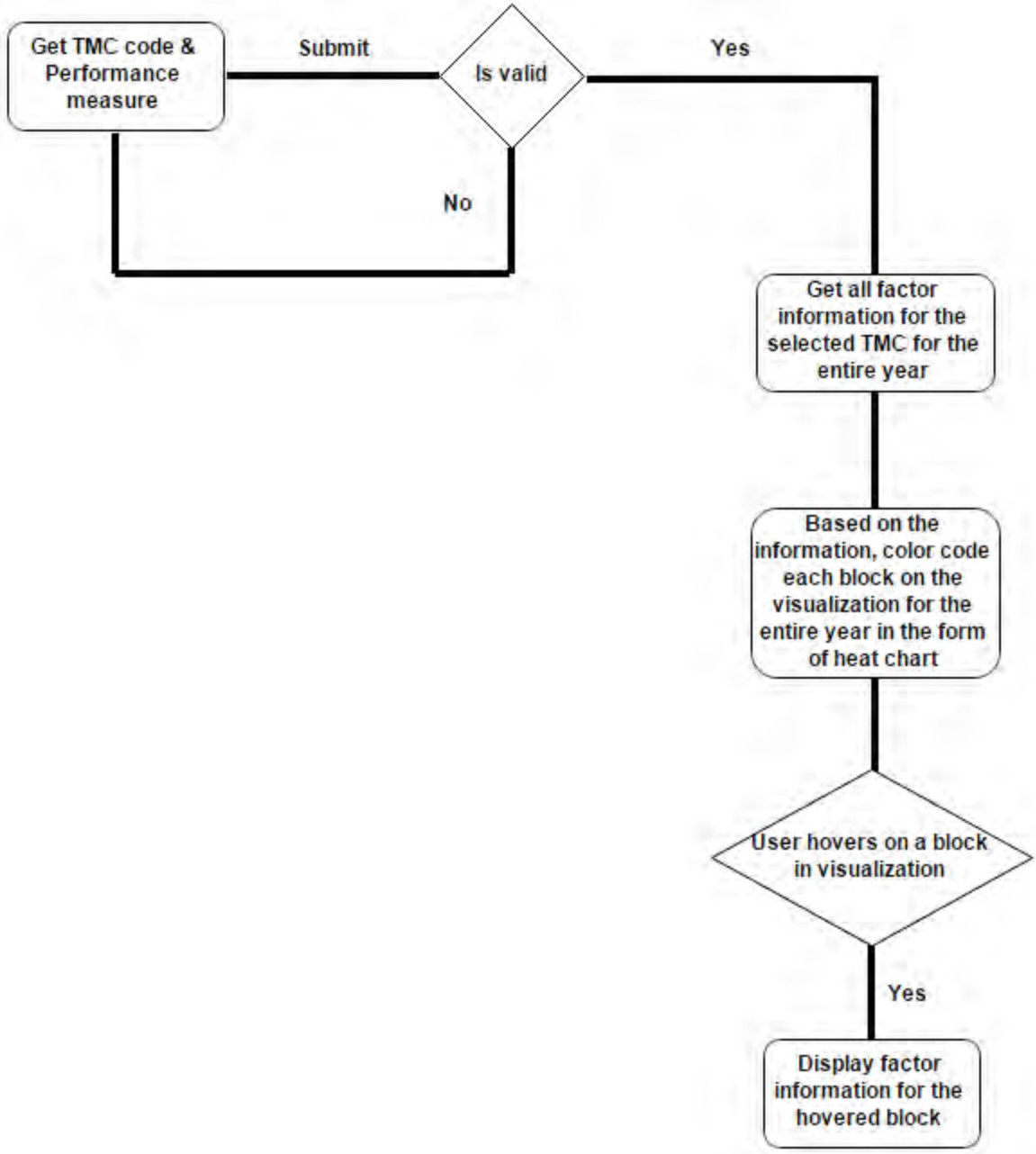

Figure 6: Architecture of "HeatChart" Visualization DST from System Perspective

4.3. Reports DST

The reports DST uses SQL Server's Reporting Services (SSRS) to generate a report based on selected options such as year, TMC code, time-of-the-day and day-of-the-week. It can be accessed by using the "Reports" tab of the application. Figure 7 shows the flowchart describing the architecture of reports DST at system perspective.

The year, day-of-the-week, time-of-the day and the TMC code are provided as input parameters through the web interface. The SSRS retrieves all the relevant data from the database. The DST is built such that it can retrieve data even for multiple input parameters. The data

retrieved is then represented in the form of a report. The right side of each column header will have an up and down arrows to sort the data retrieved. The DST also provides an option to save the output in the selected format (xml, pdf, or xlsx).

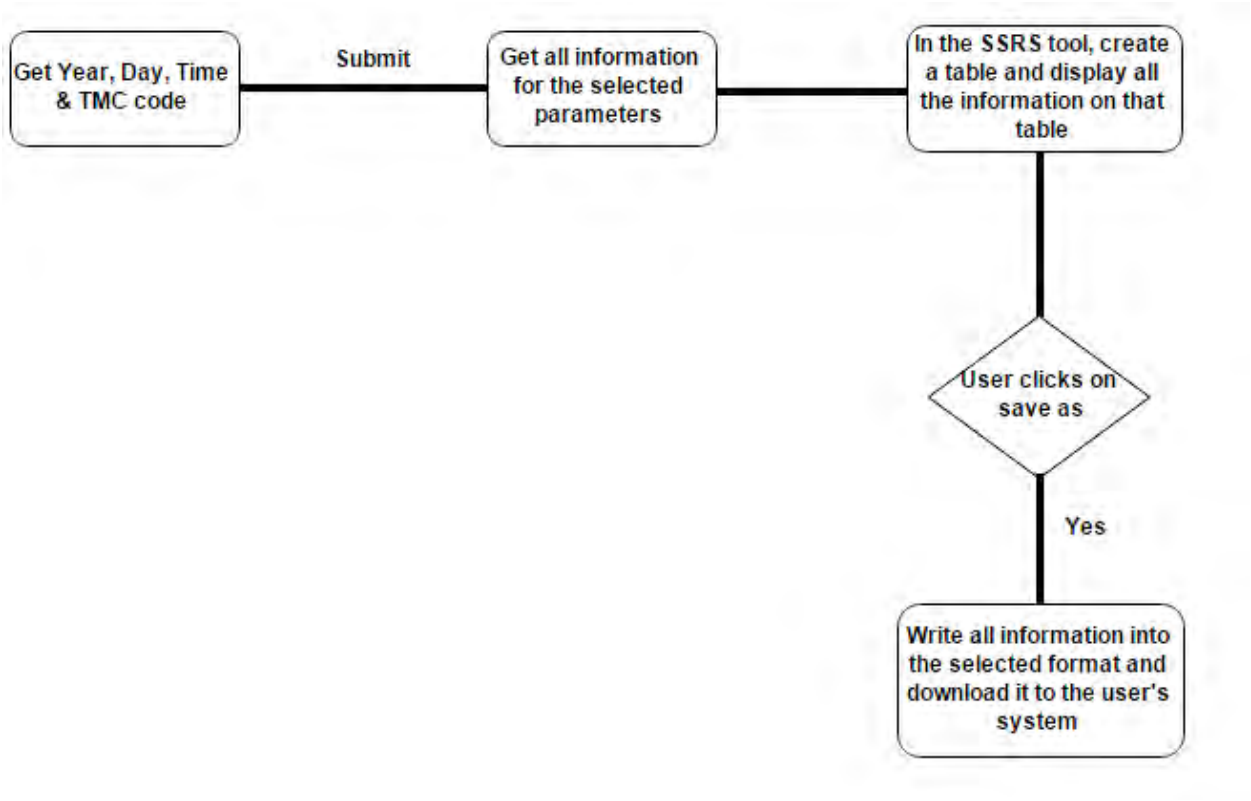

Figure 7: Architecture of Reports DST from System Perspective

4.4. Effect of Incident DST

The effect of incident DST shows the effect on an incident (crash) on the surrounding links of the transportation network. It uses MapQuest map to spatially represent the effect of an incident over time and space. Figure 8 shows the flowchart describing the architecture of effect of incident DST at system perspective.

The severity of an incident (crash information in the database), day-of-the-week and time-of-the-day are provided as input parameters through the web interface. Based on the input parameters, this DST retrieves all the roadway links with selected crash severity. The parameters such as road name and the radius from the incident (1-mile, 2-mile, 3-mile, 4-mile and 5-mile) are then selected from the dropdown menu. The location of the incident will be extracted from the incident database and is shown on the MapQuest map as a marker. A single mouse click on the marker opens the tooltip with the information related to the incident. Also, a link is provided on the tooltip to show the effect of the incident on the surrounding links within the selected radius. On clicking it, the DST retrieves average travel time variations for every 15-minute intervals on all the links around the given radius from the location of the incident for 30 minutes before the time of incident to 2 hours after the time of incident.

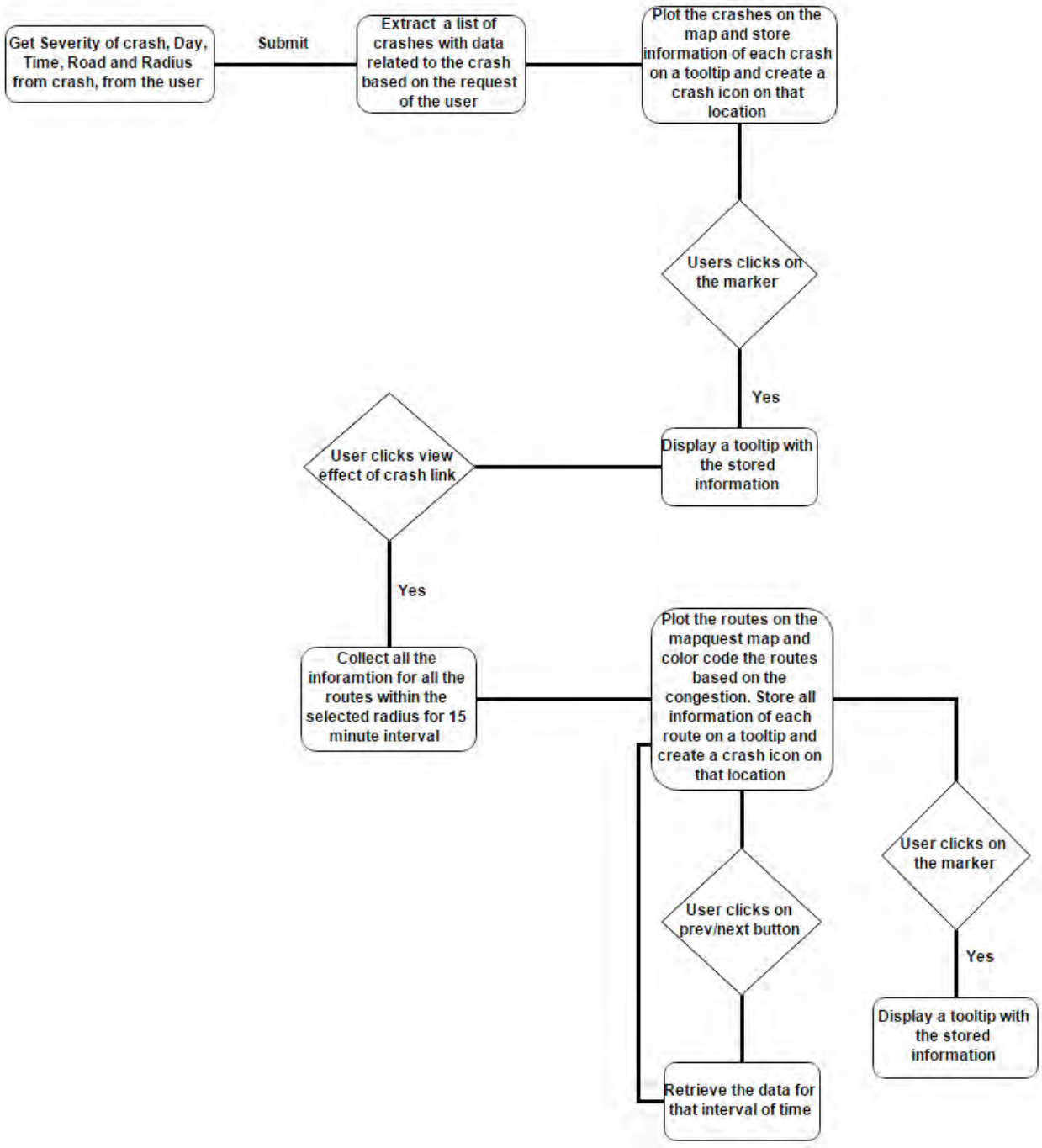

Figure 8: Architecture of Effect of Incidents DST from System Perspective

The travel time variation on a link is computed as the percentage increase in the travel time during the incident with respect to average travel time on the same link without an incident (same time-of-the-day and day-of-the-week). In the data retrieved, each link in the transportation network is uniquely identified by its respective TMC code. It then plots each TMC code on the MapQuest using "from-to" coordinates. Each link is color coded based on the percentage

variation of travel times. A red marker is placed on each TMC code where all the related information for the TMC code is stored.

By default, the DST shows the travel time variation of nearby links in the transportation network at a time 15-minutes before the incident. The DST is provided with clickable buttons to navigate through previous and next 15-minute intervals to visualize the effect of incident on the nearby links in the transportation network (over time) for the next two hours. Figure 9 illustrates the working of the effect of incident DST.

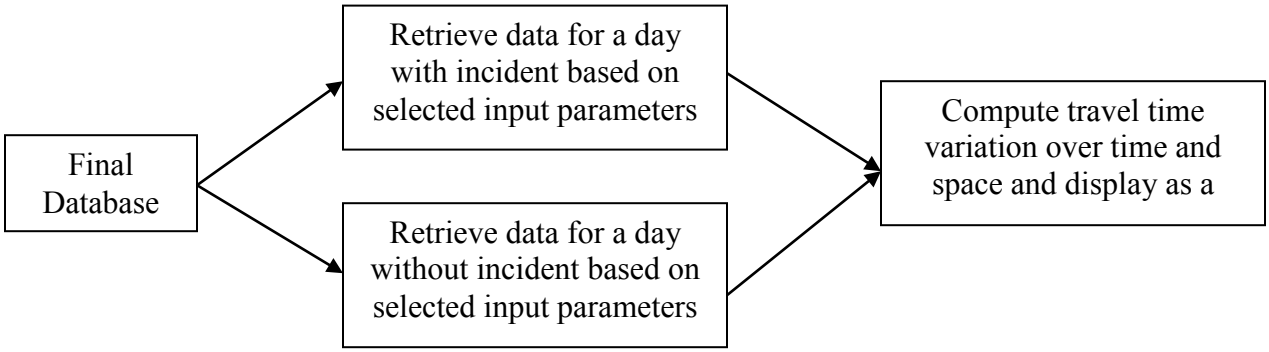

Figure 9: Data Processing and Computing Travel Time Variation Due to an Incident

CHAPTER 5: USER INTERFACE

Four interactive DSTs were developed as a part of this project. They are: 1) Reliability Mapping DST, 2) "HeatChart" Visualization DST, 3) Reports DST, and, 4) Effect of Incident DST. The DSTs are built with analytical and visual capabilities to assess and report condition of the transportation network as well as facilitate practitioner's need in identifying and prioritizing links for improvements.

The following sections describe how the DSTs developed can answer each of the following questions.

1. How does performance of links vary spatially, by the time-of-the-day, day-of-the-week, and year?
2. How could one identify unreliable links on a selected corridor in the transportation network?
3. What are the top "N" congested (unreliable) links in the transportation network for prioritization and allocation of limited resources?
4. How does the reliability of link vary by time-of-the-day and day-of-the-week during a year?
5. What is the effect of an incident on the surrounding links? How far does it extend and how does it vary over time?

5.1. Reliability Mapping DST

This DST has the ability to spatially depict reliability of selected link or links on a map. It can also be used to identify top 'N' unreliable links or sections (visually) in the transportation system. Figure 10 describes the architecture of the reliability mapping DST from user perspective. Some of the basic features of the reliability mapping DST are the ability 1) to zoom in and zoom out of the map to visualize the information at macroscopic and microscopic levels, 2) to zoom in and view information on the tooltip provided for each link in the map, and, 3) to query data and visualize data based on the search filters such as year, day-of-the-week, time-of-the-day, and reliability performance measure.

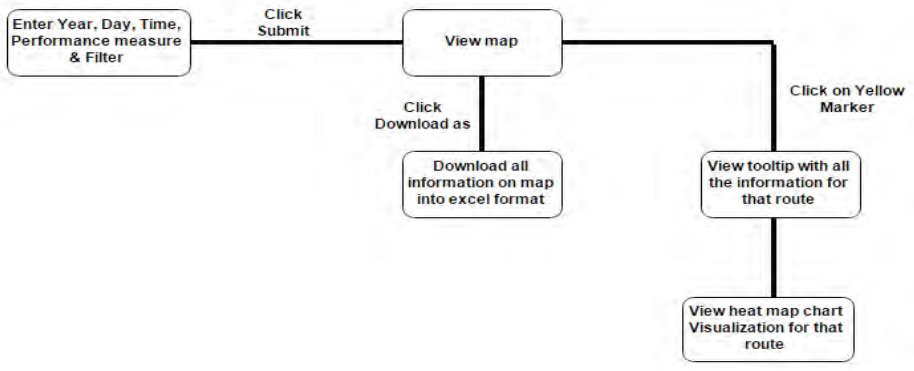

Figure 10: Architecture of Reliability Mapping DST from User Perspective

5.1.1. Assessing the Condition of Transportation Network

Delays in the transportation system are caused because of insufficient capacity in the system to handle the demand. These delays could be highly fluctuating (inconsistent) based on time-of-the-day and day-of-the-week, especially on highways and freeways. It is very important for planners to evaluate reliability of each link in the transportation network and assess the condition of transportation system. The reliability mapping DST developed helps assess the condition of transportation system through spatial representation of reliability of each link by time-of-the-day and day-of-the-week for each selected year. Spatial representation of reliability of the transportation network helps planners easily compare the performance of two links and identify the unreliable segments in the transportation network during the selected time-of-the-day and day-of-the-week. In case of any need to further analyze the data based on the selected input parameters, practitioners can download the processed data for all links with all performance measures (not just the selected factor or performance measure) into a Microsoft Excel spreadsheet. The following steps describe how to use the reliability mapping DST to assess the condition of transportation network.

Step 1: Select year, day-of-the-week, time-of-the-day and the factor / performance measure (Planning Time Index - PTI, Buffer Time Index - BTI, Travel Time Index - TTI, λ variance - Gamma Var, or Average Travel Time - Travel Time) as shown in the Figure 11.

Figure 11: Snapshot of Reliability Mapping DST - Selecting the Input Parameters

Step 2: Select "All Links" to spatially represent reliability of all the links in the transportation network.

Step 3: Submit request to view link level reliability of the entire transportation network as shown in Figure 12. From Figure 12, based on the color one can easily identify the most unreliable and reliable links in the entire transportation network for the selected time-of-the-day and day-of-the-week. In the figure, the links with black and red color are highly unreliable, whereas links that are color coded with green are reliable links.

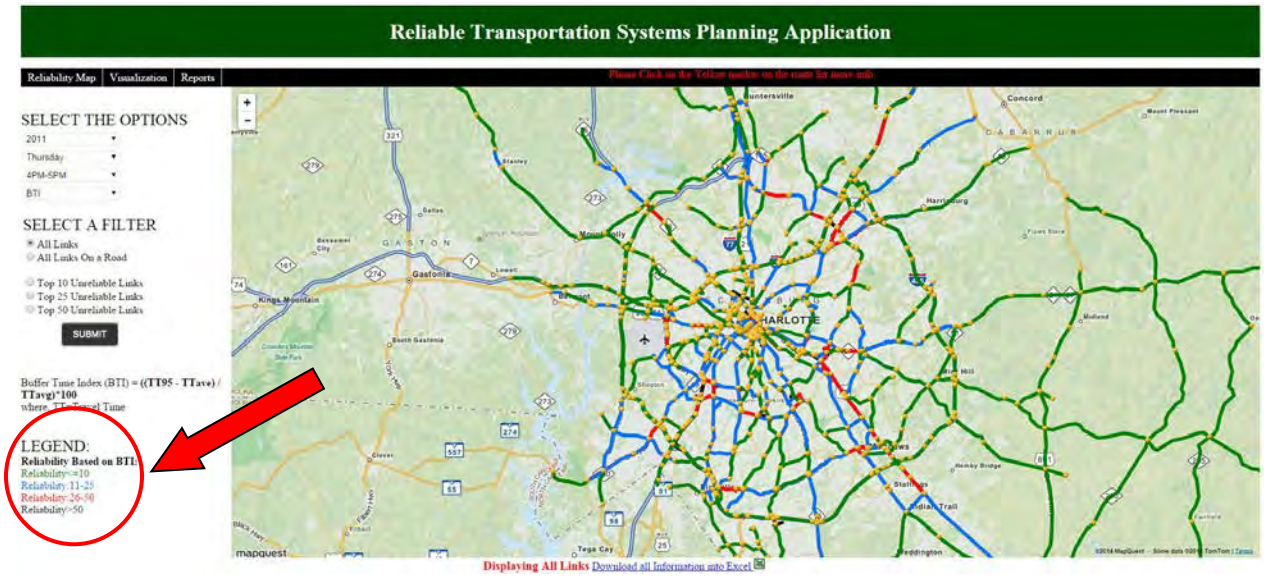

Figure 12: Snapshot of Reliability Mapping DST - Displaying Performance Measure for All Links

Step 4: Click on the "yellow marker', which is located at the beginning of each link (TMC code) on the map. A pop-up will appear with details of the selected link (as can be seen in Figure 13).

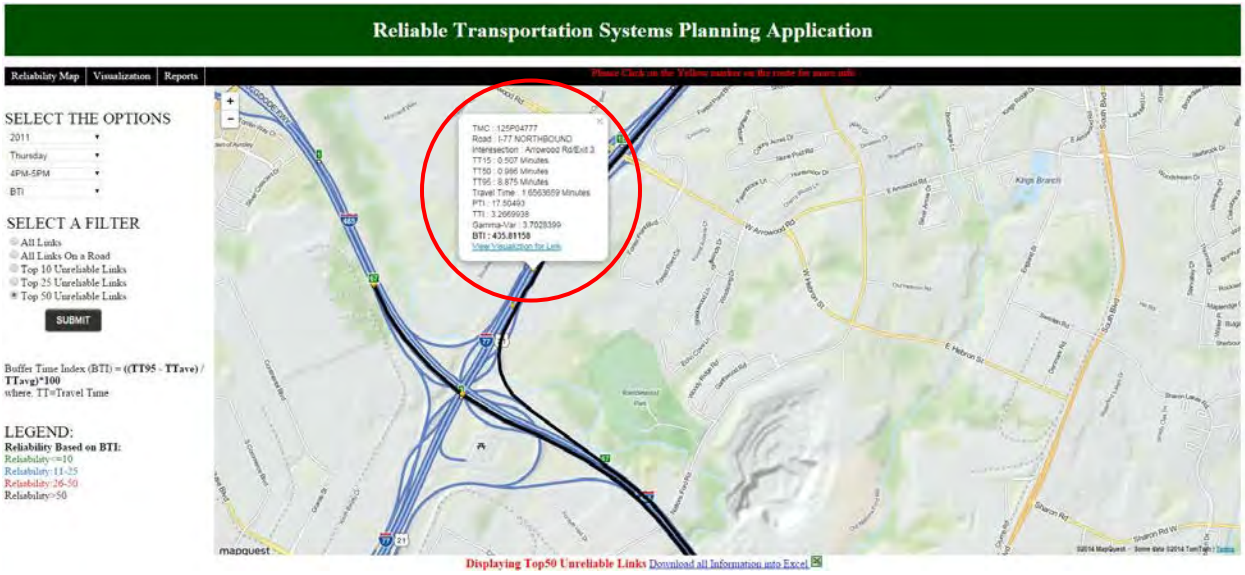

Figure 13: Snapshot of Reliability Mapping DST – Information at Tooltip

Step 5: Click on the "Download All the Information into Excel" link which is located below the map to download all the data related to the selected parameters into a Microsoft Excel spreadsheet as shown in the Figure 14.

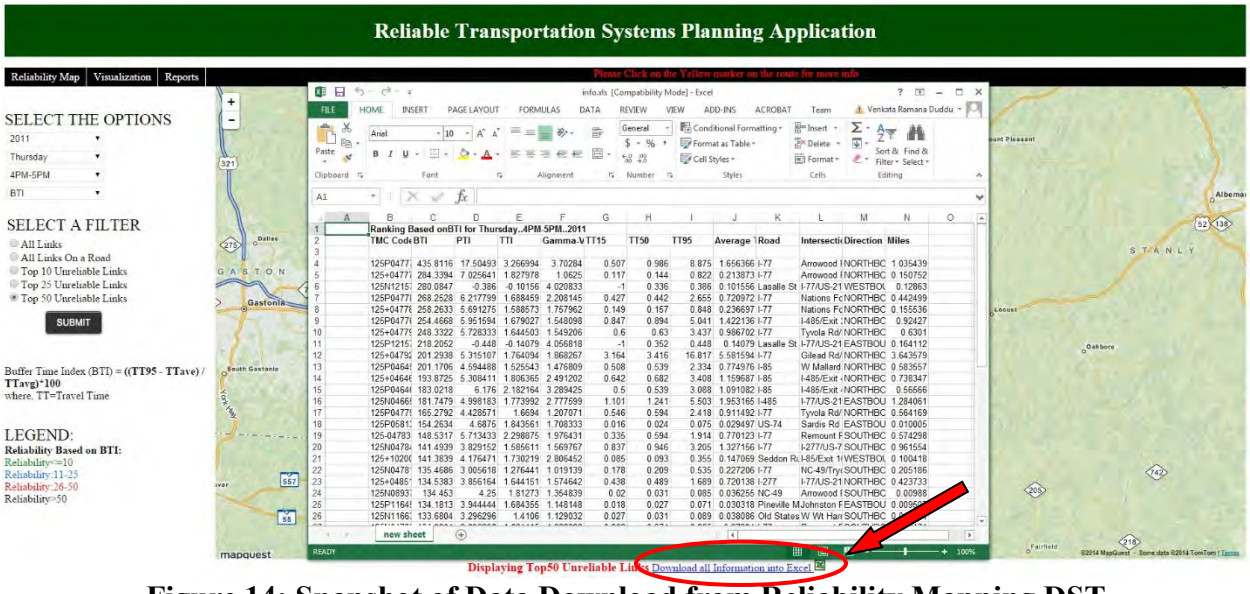

Figure 14: Snapshot of Data Download from Reliability Mapping DST

5.1.2. Assessing the Condition of a Selected Corridor

Planners and engineers quite often are interested in evaluating the performance of a particular corridor rather than the entire transportation network. The reliability mapping DST developed also helps evaluate the performance of a selected corridor and identify unreliable links along the corridor. In case of any need to further analyze the data related to the corridor and selected input parameters, practitioners can download the processed data with all performance measures into a Microsoft Excel spreadsheet. The following steps describe how to use the reliability mapping DST to assess the condition of a corridor.

Step 1: Select year, day-of-the-week, time-of-the-day and the factor / performance measure (Planning Time Index - PTI, Buffer Time Index - BTI, Travel Time Index - TTI, λ variance - Gamma Var, and Average Travel Time – Travel Time) as shown in the Figure 11.

Step 2: Select a particular roadway (say, I-85) from the dropdown list to spatially represent its performance.

Step 3: Submit the request to view performance measure of a particular roadway as shown in Figure 15. From Figure 15, one can easily identify the most unreliable links (color coded with black) on I-85 corridor and suggest necessary improvements. Similarly, as mentioned in the legend, the green color links tends to be more reliable than any other links on the I-85 corridor.

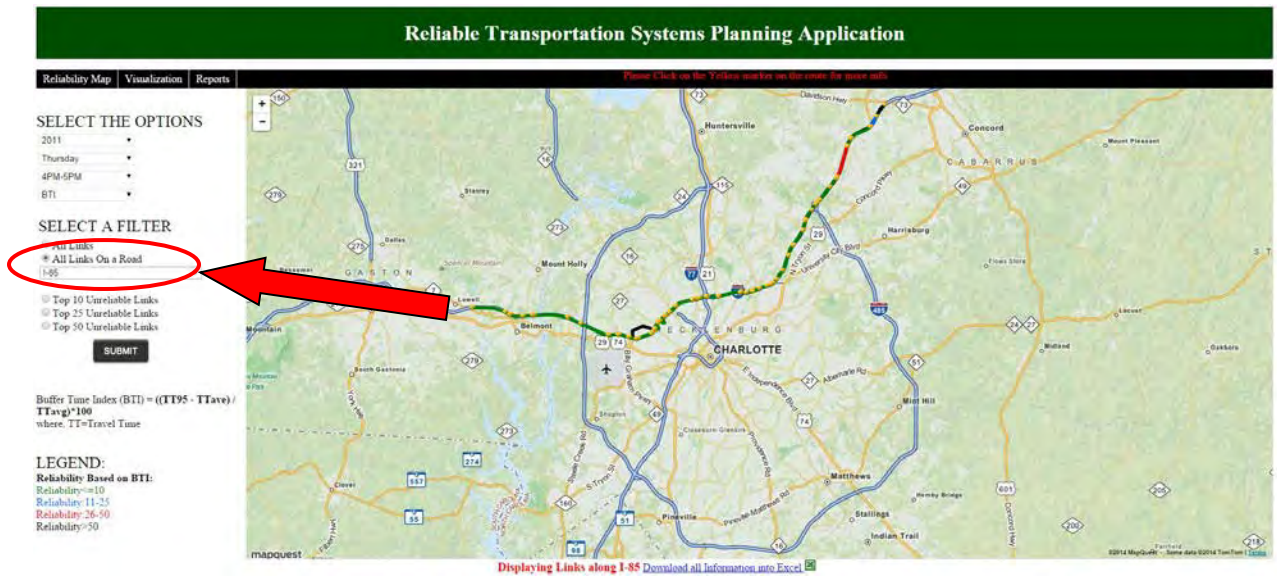

Figure 15: Snapshot of Reliability Mapping DST - Displaying Performance Measure for a Selected Corridor (I-85)

Step 4: Click on the "yellow marker', which is located at the beginning of each link (TMC code) on the map. A pop-up will appear with details of the selected link (similar to one in Figure 13).

Step 5: Click on the "Download All the Information into Excel" link which is located below the map to download all the data related to the selected input parameters into a Microsoft Excel spreadsheet as shown in the Figure 14.

5.1.3. Identifying Top "N" Unreliable Links in the Transportation Network

A delay due to a single highly unreliable link in the transportation network can propagate to the nearby links in the transportation network. Identifying the top unreliable links in the transportation network will help reduce the overall delays and also help agencies and practitioners to prioritize and allocate limited available transportation dollars. The reliability mapping DST helps identify top "N" (10, 25 or 50) unreliable links in the transportation network for the selected year, time-of-the-day and day-of-the-week. In case of any need to further analyze the data related to the top "N" unreliable links in the transportation network, practitioners can download the processed data for all unreliable links with all performance measures for the selected criteria into a Microsoft Excel spreadsheet. The following steps describe how to use the reliability mapping DST to identify top "N" unreliable links in the transportation network.

Step 1: Select year, day-of-the-week, time-of-the-day and the factor / performance measure (Planning Time Index - PTI, Buffer Time Index - BTI, Travel Time Index - TTI, λ variance - Gamma Var , and Average Travel Time – Travel Time) as shown in the Figure 11.

Step 2: Select top '10', '25' or '50' unreliable links from the options provided.

Step 3: Submit request to view top "N" unreliable links (say, 50) in the transportation network as shown in Figure 16. The figure shows all the top 50 unreliable links in the transportation network

during Tuesdays from 4 PM - 5 PM making it very easy to identify links or section to prioritize resources and implement transportation improvement projects.

Figure 16: Snapshot of Reliability Mapping DST - Top '50' Unreliable Links

Step 4: Click on the "yellow marker', which is located at the beginning of each link (TMC code) on the map. A pop-up will appear with details of the selected link (similar to one in Figure 13).

Step 5: Click on the "Download All the Information into Excel" link which is located below the map to download all the data related to the selected input parameters into a Microsoft Excel spreadsheet as shown in the Figure 14.

5.2. "HeatChart" Visualization DST

This DST summarizes performance measure of the selected link, for all days of week and times of day using data for the entire year, as a circular heat chart. The heat chart allows the end user to identify the most unreliable day-of-the-week and time-of-the-day in a year for the TMC code. It also provides a visual summary of total unreliablility duration for a given link for every day-of-the-week. Figure 17 describes the architecture of the "HeatChart" visualization DST from user perspective.

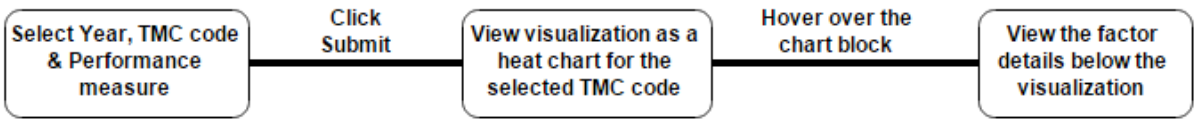

Figure 17: Architecture of "HeatChart" Visualization DST from User Perspective

5.2.1. Assessing the Performance of a Link by Time-of-the-Day and Day-of-the-Week

The previous section described how to identify unreliable links in the transportation network or on a corridor and to identify top "N" unreliable links for a selected time-of-the-day and day-of-

the-week. However, it is very important to evaluate how the performance measure of the link varies by time-of-the-day and day-of-the-week during a year i.e., to evaluate if the link is unreliable only during peak hours or to assess during which times-of-the-day and day-of the-week's the link is unreliable. The following steps describe how to use the "HeatChart" visualization DST to assess the performance of a link by time-of-the-day and day-of-the-week during a year.

Step 1: Select the year, TMC code and the factor / performance measure (Planning Time Index - PTI, Buffer Time Index - BTI, Travel Time Index - TTI, λ variance - Gamma Var , and Average Travel Time – Travel Time) as shown in Figure 18.

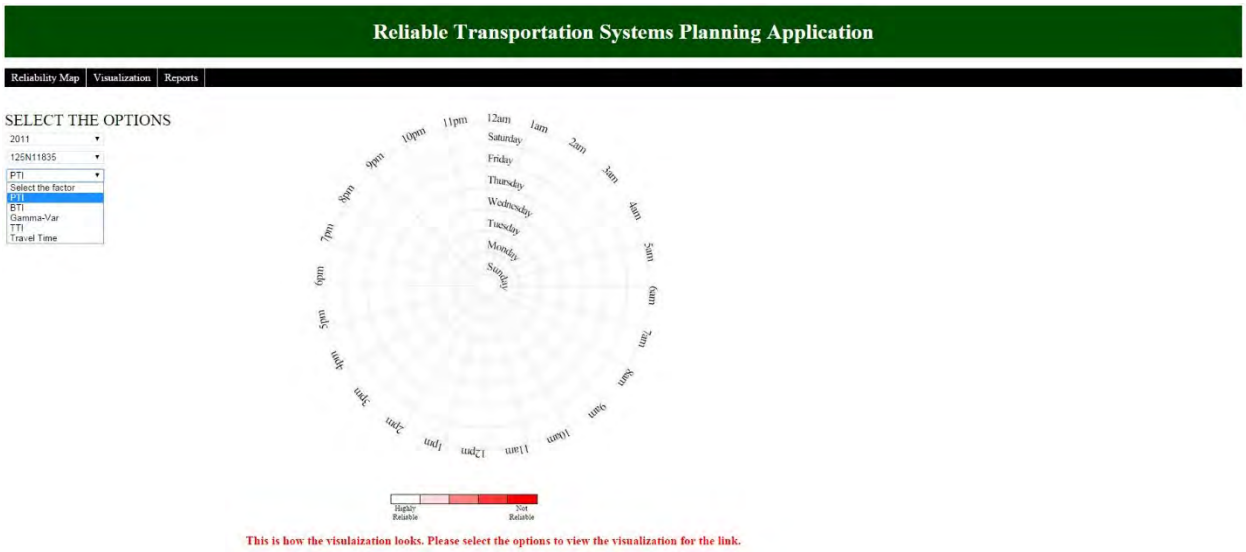

Figure 18: Snapshot of "HeatChart" Visualization DST - Selecting the Input Parameters

Step 2: Submit request to view the heat chart for the link as shown in Figure 19. The figure shows that the given link is unreliable during weekdays continuously from morning 8 AM till 6 PM in the evening. Similarly, the duration of unreliability for any other link in the transportation network can be accessed from the developed heat chart based on selected input parameters.

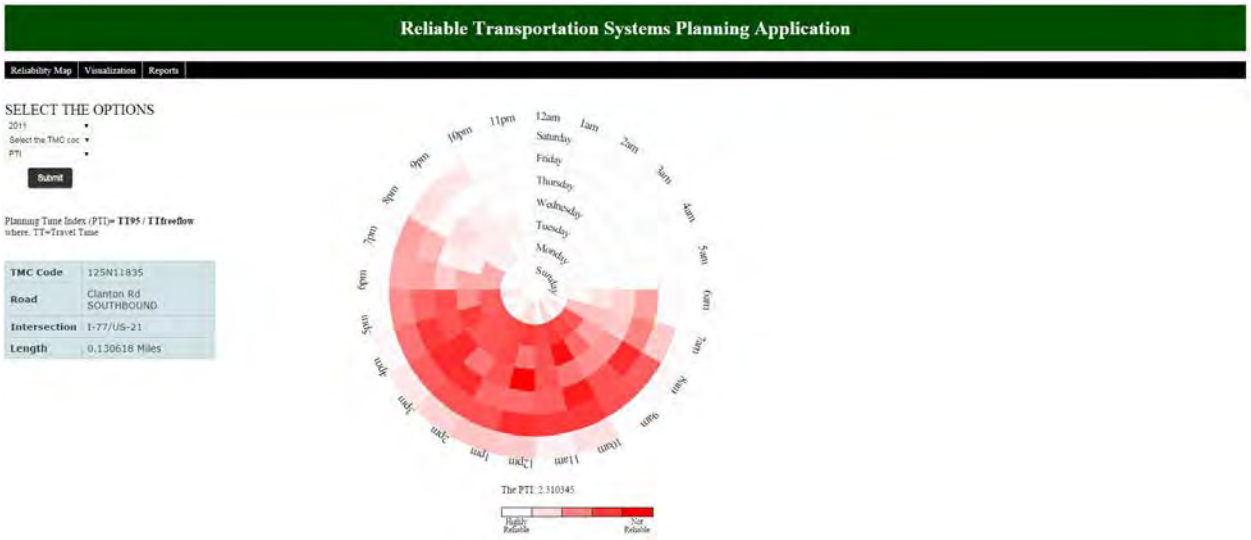

Figure 19: Snapshot of Output of "HeatChart" Visualization DST

5.3. Reports DST

This DST allows the practitioner to download all the relevant travel times and reliability performance measures data for multiple years, TMC codes and days of the week in to a Microsoft Excel spreadsheet. The data downloaded can be used for any further analysis or inclusion as part of project reports. Figure 20 describes the architecture of the reports DST from user perspective.

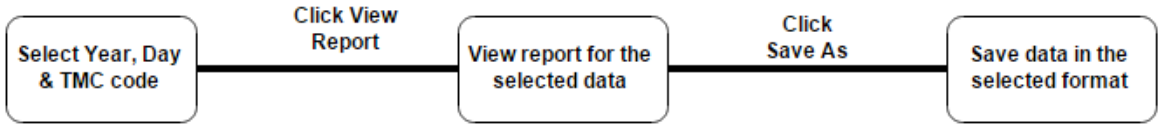

Figure 20: Architecture of Reports DST from User Perspective

5.3.1. Retrieve and Report Performance Measures Data

Currently, most of the transportation agencies use travel time estimates from Bureau of Public Roads equation or other sources in travel demand modeling process due to the unavailability of travel time performance measures data for most of the links in the transportation network. The availability of performance measures data by time-of-the-day and day-of the-week for the transportation network opens avenues to use this information to calibrate and improve accuracy of travel demand models. The reports DST developed can help download the performance measures data for selected year or multiple years, selected time-of-the-day (peak hours) or multiple times of the day and for select day-of-the-week or multiple days of the week, for all the links in the transportation network or selected links. The following steps describe how to use the reports DST to download the performance measures by time-of-the-day and day-of-the-week.

Step 1: Select the year(s), day-of-the-week and TMC codes as shown in Figure 21.

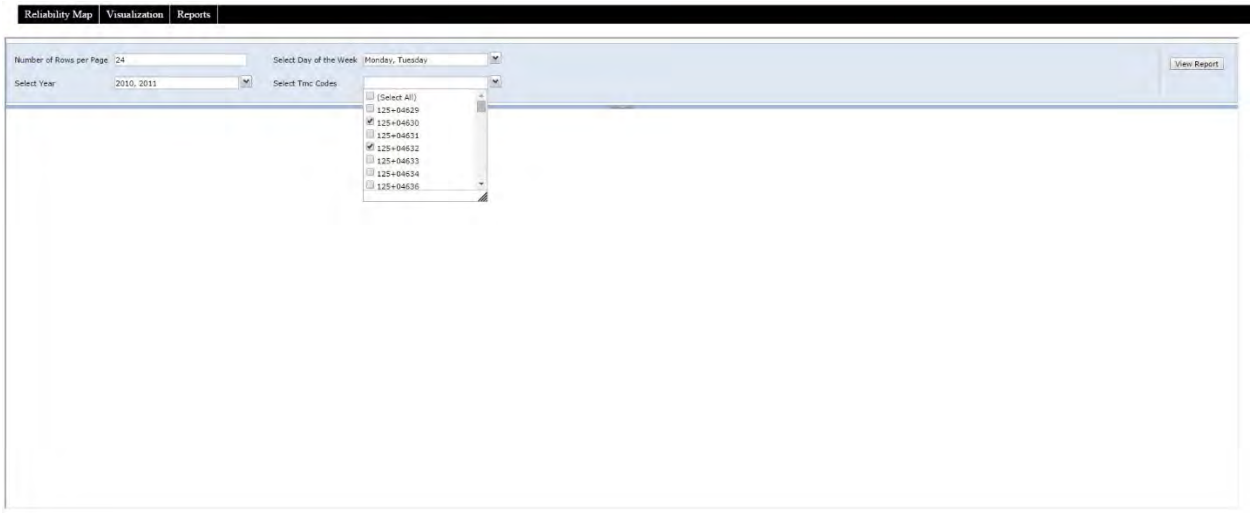

Figure 21: Snapshot of Reports DST - Selecting the Input Parameters

Step 2: Submit request to view the relevant travel times and performance measures data as shown in Figure 22.

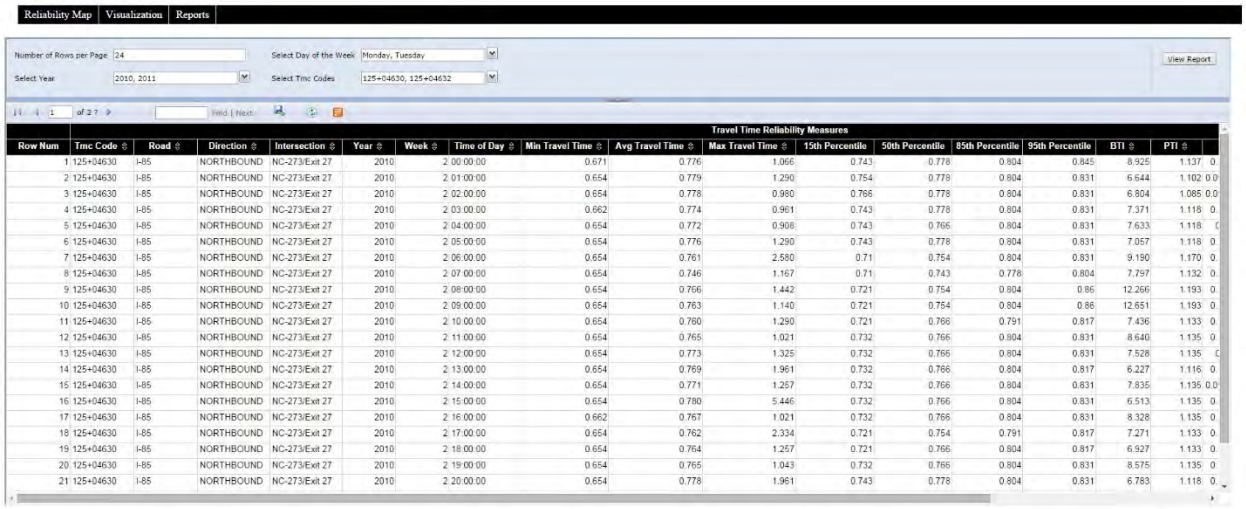

Figure 22: Snapshot of Output of Reports DST

Step 3: Click on the download button to download the data in requited format as shown in Figure 23.

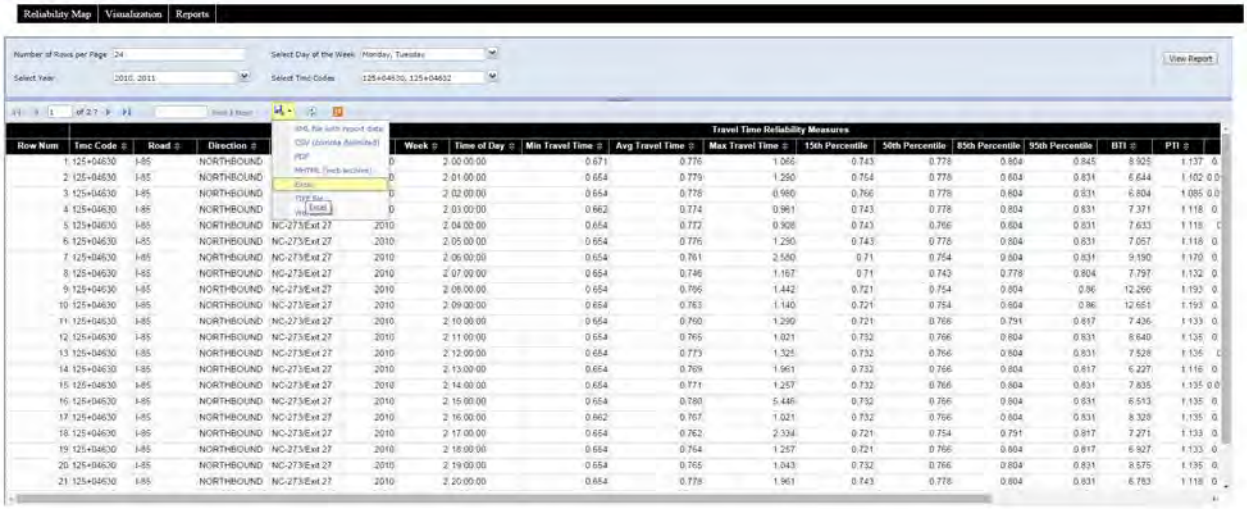

Figure 23: Snapshot of Data Download Formats in Reports DST

5.4. Effect of Incident DST

This DST shows an incident and its effect on nearby links based on percentage difference in link travel times. The travel time variation can be observed over space and time. Figure 24 describes the architecture of the effect of incident DST from user perspective. All the basic features of the reliability mapping DST such as zoom in/out feature, information on tooltip and search filters were also incorporated for the effect of incident DST.

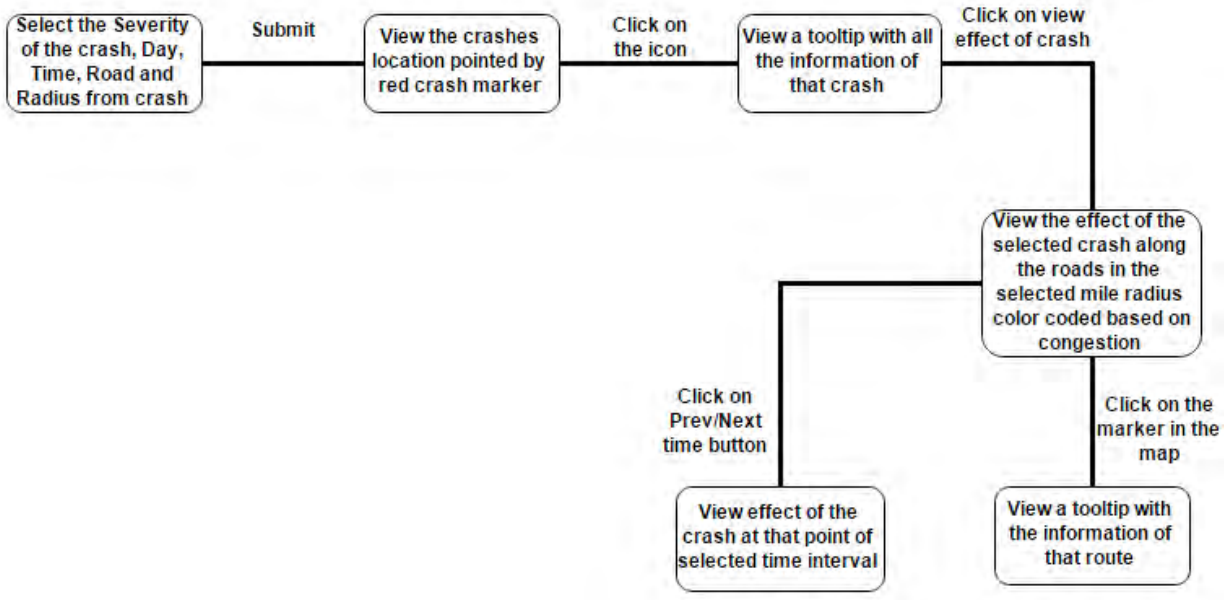

Figure 24: Architecture of Effect of Incident DST from User Perspective

5.4.1. Evaluate the Effect of Incident on Surrounding Links

Most of the non-recurring congestion in the transportation system is due to incidents. The effect of an incident on nearby links in the transportation network could vary by the time at which the incident occurred, its severity, spatial location and network characteristics. To identify effective

countermeasures (detouring, provide information through dynamic message signs, or media), a thorough understanding of the effect of an incident on the transportation network is essential. The effect of incident DST developed helps evaluate the effect of an incident by severity, time-of-the-day and day-of-the-week on nearby links. It is computed as the percentage increase in the travel time due to an incident when compared to the travel time without incident (same time-of-the-day and day-of-the-week). The output from the DST quantifies and spatially represents the effect of an incident (in terms of delays caused due to an incident). This information helps planners effectively make decisions and provide users with most reliable information regarding the delays due to an incident. It will also help identify all the nearby links in the transportation network (radius from the incident) that are affected due to the incident. The DST quantifies delays for every 15-minute interval, 30 minutes before the incident to 2 hours after the incident. This will help evaluate the total incident clearance time for an incident based on its severity, incident time and day-of-the-week. The following steps describe how to use the effect of incident DST to assess the condition of transportation network.

Step 1: Select severity of crash, day-of-the-week, time-of-the-day, street name and radius around the crash as shown in Figure 25. To show all the crashes of a given severity, once the crash severity is selected, by selecting "All Days" in the day-of-the-week dropdown, the tools shows all times of the day at which the selected severity of crashes have occurred. By selecting a particular time-of-the-day and street name, all crashes related to the selected severity that have occurred on that street during the selected time-of-the-day from 2009 to 2013 will be shown spatially on the map. This way the tool developed shows all the crashes by severity that have occurred during 2009-2013 on the selected street. However, one has to select time-of-the-day at which the crashes have occurred (shown in the dropdown of time-of-the-day option) since the effect of a crash on the nearby links vary based on the time at which the crash has occurred.

Figure 25: Snapshot of Effect of Incident DST - Selecting the Input Parameters

Step 2: Submit request to view the incident location spatially as shown in Figure 26.

Step 3: To view all the information about the selected incident, click on the incident location. A tooltip with all the information relevant to the incident will be shown (Figure 26).

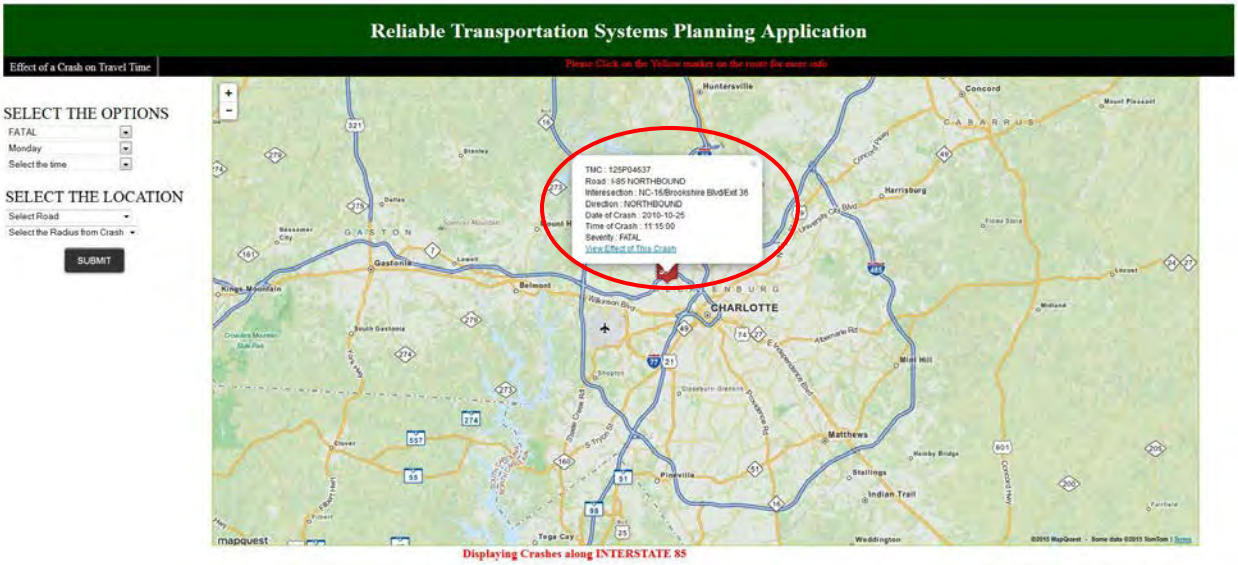

Figure 26: Snapshot of Incident Location and Tooltip Information

Step 4: Click on the "View Effect of Incident" link provided on the tooltip to examine the effect of crash on nearby links within the selected radius. The DST then shows the percentage difference in travel time on links within the selected radius at the time of crash. The percent difference in travel time is based on travel time during the period with crash and travel time during the same day-of-the-week / time-of-the-day without crash. Figure 27 shows the effect of an incident on nearby links at the time of incident.

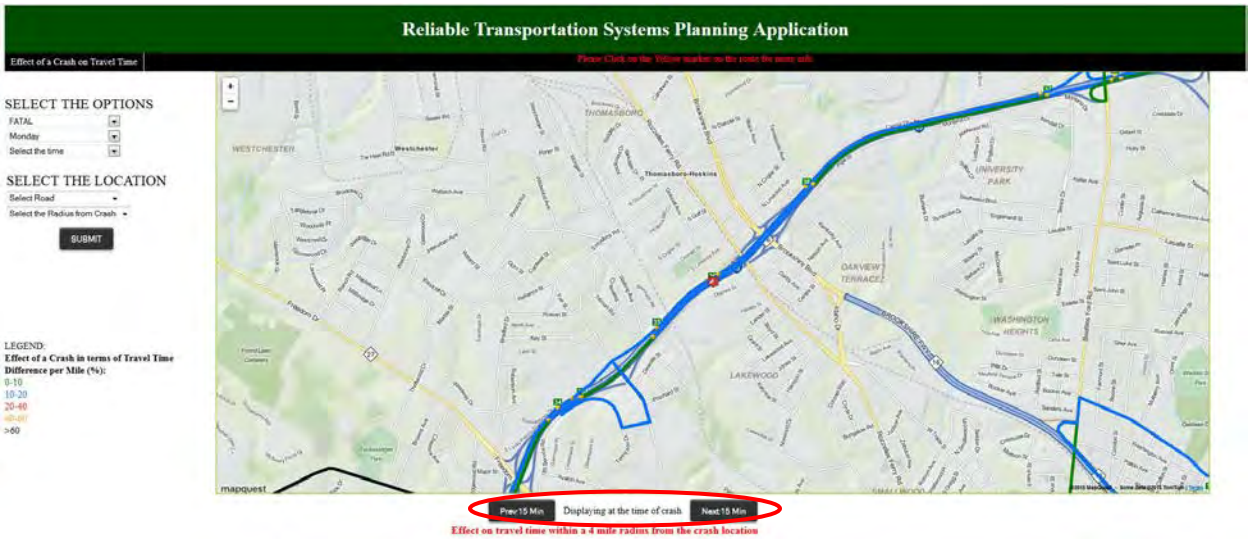

Figure 27: Snapshot of Effect of Incident at the Time of Incident

Step 5: The Prev 15-min and Next 15-min buttons will help the end user observe the percentage difference in travel time similarly over the 2-hour period. Figure 28 shows the effect of incident

30 minutes after the time of crash. From Figure 27 and Figure 28, 30 minutes after the crash, the travel time of the adjacent links to crash location increased from 20% to 40%. Similarly, travel time variations on the surrounding links and their extent can be easily evaluated for any given crash using the DST developed.

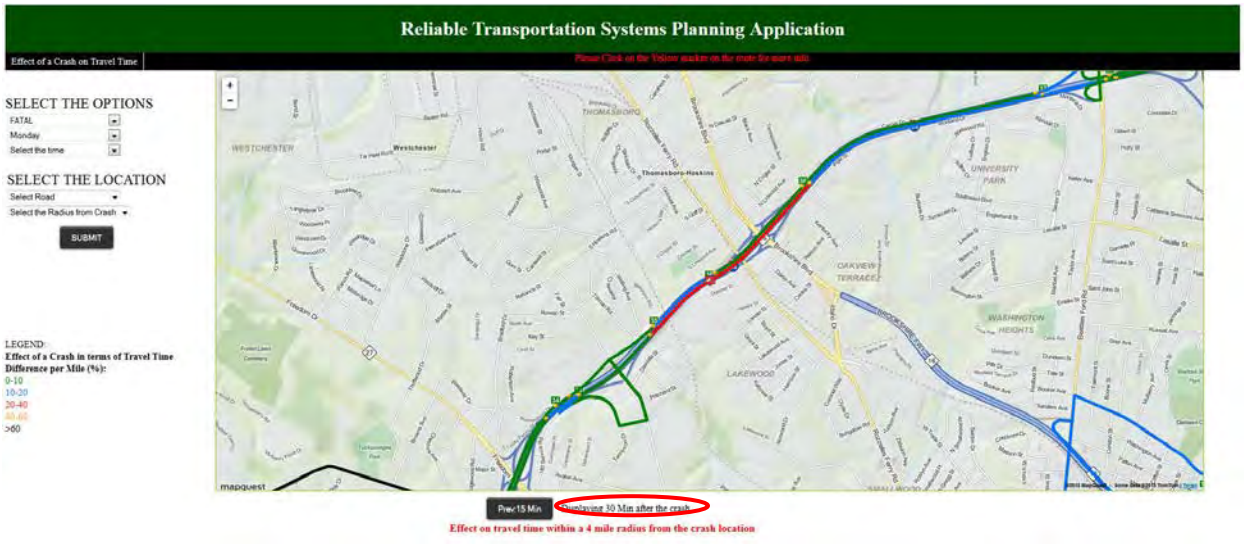

Figure 28: Snapshot of Effect of Incident 30 Minutes after the Time of Incident

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This project report presents four interactive DSTs with analytical and visual capabilities to assist practitioners make decisions pertaining to transportation system. They are: 1) Reliability Mapping DST, 2) "HeatChart" Visualization DST, 3) Reports DST, and 4) Effect of Incident DST. These DSTs help practitioners perform the following.

1) Assess the condition of the transportation network based on various performance measures
2) Assess the condition of a given corridor in the transportation network
3) Identify top "N" unreliable links in the transportation network
4) Assess the performance of a link by time-of-the-day and day-of-the-week during a year
5) Retrieve and report performance measures data for any further analysis
6) Evaluate the effect of incidents on the surrounding links in the transportation network

Each DST performs a dedicated function to easily navigate through different features of the overall application. The two geospatial based DSTs (reliability mapping DST and effect of incident DST) use MapQuest map to spatially represent the selected performance measure. The "HeatChart" visualization DST generates a heat chart, while the reports DST retrieves data and generates output through the SQL Server Reporting Services.

The geospatial based reliability mapping DST developed has seamless transition from macroscopic level (transportation network-level) to details at a microscopic level (link-level). The macroscopic level details help assist decision-makers and practitioners in transportation planning and development of performance-based congestion management plans. The microscopic level details help engineers in identifying site-specific solutions and improvements. This DST also helps identify top 'N' (10, 25 and 50) unreliable links in the transportation network for prioritization and allocation of resources.

The "HeatChart" visualization DST helps visualize performance measure of the selected link by time-of-the-day and day-of-the-week during a year. This DST helps identify critical unreliable time periods by day-of-the-week in that year. The practitioner will be able to visualize the intensity and duration of performance measure by time-of-the-day to plan and improve mobility as well as safety.

The reports DST retrieves, disseminates and reports travel times and reliability measures by time-of-the-day and day-of-the-week for selected years. The practitioners can generate reports and store them in their local storage devices to use it for any other purpose of their interest. For example, the outputs from the DSTs developed can be used in the travel demand modeling process to better calibrate and enhance accuracy of the outputs generated through the process.

The effect of incident DST shows the effect of an incident over time and space. This DST helps identify critical links to divert traffic due to an incident - incident management and re-routing traffic.

Overall, the DSTs developed and implemented such as those as a part of this project are expected to add value and enhance business practices adopted by state and local agencies. These DSTs also assist transportation network users make reliable route, mode and departure time decisions. Emergency response units can use the information to select reliable paths to provide timely services. FedEx, USPS, UPS, etc. can use the information to avoid unreliable paths and deliver goods on time.

Availability of travel time data for all links (major as well as minor roads) in the transportation network will certainly add value and enhance the DSTs. Also, integrating at a system level with other components such as weather data, traffic counts, event planning, incidents such as mechanical breakdown of vehicles, and construction activities will improve and enhance the effectiveness of DSTs in making transportation related decisions.

Transportation planning, project prioritization and ranking decisions are typically made at regional or local level. Considering the nature of these decisions, it is recommended that DSTs developed and discussed in this report be implemented at regional or local level.

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