EXAMINING THE ASSOCIATION BETWEEN BUS TRANSIT RELIABILITY AND RIDERSHIP

by

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A thesis submitted to the faculty of
the University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Master of Science in
Civil Engineering

Charlotte

2021

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ABSTRACT

SRAVYA L. JAYANTHI. Examining the Association Between Bus Transit Reliability and Ridership. (Under the direction of DR. SRINIVAS S. PULUGURTHA)

The road infrastructure has not been developed at the rate of growing travel demand in many cities in the United States, mainly due to space and resource constraints. Practitioners are exploring means to increase public transportation ridership with economically efficient investment plans to cater the travel demand, reduce congestion, and contribute to sustainability. Despite these ongoing efforts, recent statistics indicate that public transportation ridership has decreased in many cities in the United States, and bus ridership alone fell by 5% in 2017 compared to the previous year. There is a need to research and identify factors that encourage the use of public transportation systems over other modes of transportation.

The research explaining the relationship between bus transit reliability and ridership is limited. The reliability of a bus transit system by bus stop type, time of the day, day of the week, and direction of travel may influence the ridership. In other words, it is not clear how bus transit reliability influences the ridership temporally and spatially at a bus stop level. Therefore, this research aims to examine the association between bus transit reliability and ridership from a bus user perspective at a bus stop level.

The objectives of this research are: 1) to identify and better understand the bus transit reliability performance measure, 2) to analyze the relationship between bus transit reliability and ridership, by considering the time of the day, day of the week, and direction of travel, and 3) to research the effect of bus stop type (for example, transit center, bus stop

near a light rail transit [LRT] station, transit centers near LRT etc.,) on bus transit reliability and ridership relationships.

The city of Charlotte in North Carolina was considered as the study area. All data pertaining to bus transit reliability and ridership was gathered from the Charlotte Area Transit System (CATS) for the year 2017. The data was processed to compute bus transit reliability and ridership at the bus stop level.

A total of 394 bus stops were considered for the analysis. The on-time performance (OTP) percentage was considered as the bus transit reliability measure while the average number of boarding was considered as ridership. The OTP percentages were computed comparing the scheduled and actual departure times (-1 to +5 min and -1 to 3min). In other words, the bus transit reliability threshold is set using an acceptable range from 1 minute early to 5 minutes late or 1 minute early to 3 minutes late. The results from the D'Agostino's Pearson K^2 test indicate that the data is normally distributed at a 95% confidence level. Therefore, the relationship between the bus transit reliability and ridership was evaluated using Pearson correlation analysis.

The Pearson correlation analysis was carried out at four levels: considering the day of the week, time of the day, direction of travel, and bus stop type. The results for a typical service day indicated that a bus transit user boards the bus if it departs on-time, irrespective of whether the bus arrives on-time or not. Four different peak hours of the day were considered and analyzed to better understand this association over different times of the day. The results showed that the association between bus transit reliability and ridership is more significant in the morning and night-time hours, accounting for the work trips made by the bus transit users.

Interpreting the association based on the trip purpose paved the way to explore the relationship between bus transit reliability and ridership by considering the direction of travel. A high positive correlation between bus transit reliability and ridership was observed in the morning peak and night-time hours. This indicates the high reliability requirement for work trips in the inbound direction travel (morning peak hour) and outbound direction travel (nighttime hour).

The nature of the relationship between the bus transit and ridership still remained unclear when intermodal effects like the LRT was considered. Reliability certainly is one of the most important service characteristics to transit customers, while operating in coordination with the other transit service like LRT is linked with customer satisfaction. The bus stops were segregated based on their spatial location from the LRT stations. The results based on the bus stop type indicated a higher positive correlation between bus transit reliability and ridership at bus stops near LRT stations than bus stops located far away from the LRT station. Transit centers that serve as transfer stops have high bus transit reliability, which attract more people to use the bus transit system. The Pearson correlation analysis based on the direction of travel and bus stop type indicated a more significant association between the bus transit reliability and ridership at bus stops near LRT and in the outbound direction of travel.

The methodological framework illustrated in this research helps understand the influence of bus transit reliability on ridership at a bus stop level from a transit user perspective. The findings from this research help practitioners and professionals better plan, design, and operate the transit system in an urban area and assess to what extent a reliable transit system influences its ridership.

DEDICATION

To my parents for their love and support throughout

Thank you for everything

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere and deepest gratitude to my advisor, Dr. Srinivas S. Pulugurtha, Professor of Civil and Environmental Engineering, The University of North Carolina at Charlotte. His expertise, invaluable guidance, constant encouragement, patience, and dedication had been solely and mainly responsible for completing my work. Without his inspiration, motivation, and persistent help, completing this research would not have been possible.

I would like to thank my committee members, Dr. Martin Kane and Dr. Rajaram Janardhanam, for their continued support and guidance.

I thank the Charlotte Area Transit System (CATS) for providing me the transit data required for my research.

I will forever be grateful to my college advisor, Dr. Mukund Dangeti, for his unwavering support, encouragement, and faith in me.

I would like to thank Ms. Prasanna Srirangam for sharing her valuable insights about this research. A special word of thanks to Chaitanya Bhure, Dr. Sarvani Duvuri, and Dr. Sonu Mathew for sharing their feedback. I thank my fellow student researchers: Raunak Mishra, Hardik Gajera, Swapneel Kodupuganti, and Raghuveer Gouribhatla for extending their unstinted support and timely motivation during my entire master’s program.

I would like to express my profound appreciation to my friends Srikar Dantuluri, Kusuma Gullamajji, and Vasuma Umareddy who were always there for me and supported me adamantly.

I am forever indebted to my Father (Sriram Murthy Jayanthi), Mother (Nagamani Jayanthi), and Brother (Sarath Jayanthi) for their unconditional love, support, and faith.

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LIST OF ABBREVIATIONS

APTA	American Public Transit Association
BRT	Bus Rapid Transit
CATS	Charlotte Area Transit System
LRT	Light Rail Transit
OTP	On-Time Performance
PMT	Passenger Miles Traveled
TCQSM	Transit Capacity and Quality Service Manual

CHAPTER 1 INTRODUCTION

Increasing population, rapid urbanization, and travel demand increase the need for public transportation systems and sustainable transportation planning. The public transportation industry in the United States is worth $80 billion (Litman 2016). In 2019 alone, 9.9 billion trips were made using public transportation systems, and they approximately account for 34 million trips each weekday (Hughes-Cromwick 2019). Despite the greater demand for public transportation, it is observed that transit ridership has not been increasing significantly in the last two decades. The current transit systems require modernization, expanded service areas, and increased service frequency with more efficiency to serve the needs of the ever-growing travel demand.

The transit ridership may depend on several factors such as availability of service, frequency, transit system reliability, accessibility to bus stops, developments ranging from manufacturing amenities, commercial centers, and business parks to the residential properties in an area. Unreliable transit services affect the commuters' trip plan and may lead to mode shift. Consequently, it may result in revenue losses to public transportation agencies and impede the sustainable transportation vision. Thus, the focus of this thesis is to research the association between bus transit reliability and ridership at a bus stop level from a transit user perspective and understand their variation over time by day of the week, time of the day, direction of travel, and type of bus stop. The findings help public transportation agencies effectively utilize available resources, plan, and provide better services to all users.

1.1 Motivation and Background

Public transportation plays a pivotal role in achieving sustainable transportation goals. Public transportation systems can efficiently move commuters to their destinations with fewer negative carbon impacts per person than privately owned transportation modes (cars) (Azizalrahman 2019). Many cities in the United States experience a steady and significant population growth causing an increase in travel demand. Over the past few decades, there has been an increase in attention towards sustainable transportation solutions that can cater to the increased travel demand. Figure 1 presents the population growth in the United States over the past two decades.

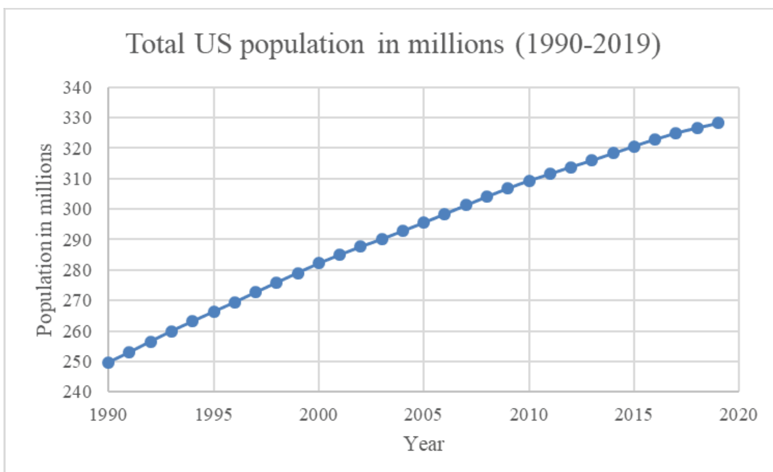


Figure 1 Population of the United States (1990-2019) (Source: U.S. Census Bureau, 2019)

The American Public Transportation Association (APTA) reports that 77% of Americans believe that public transportation is the backbone of a multi-transit lifestyle (APTA 2020). Growing cities in the present era are linked with the requirement of a reliable public transit system. Services such as the bus rapid transit (BRT), light rail transit (LRT), commuter rail, etc. are typical public transportation systems across the United States. Several strategies are being implemented to improve these facilities, including park and ride services, intermodal services, segregated right-of-way, stations involving platforms with high-quality amenities, and usage of intelligent transportation systems-based applications (Ishaq and Cats 2020; Devi et al. 2021). Improvements in the transit systems may aid in the anticipated increase in overall ridership.

Public transportation use in the United States is distributed unevenly across people and places (Hernandez 2018). Transit accounts for about two percent of all passenger miles traveled (PMT) and about two percent of overall personal trips (NHTS 2009). However, in spite of the major improvements in the public transit system, the ridership over the past two decades indicate that there was no significant change in the total ridership. Figure 2 shows the change in ridership over the past two decades with a net increase of 1 million from 1990 until 2019.

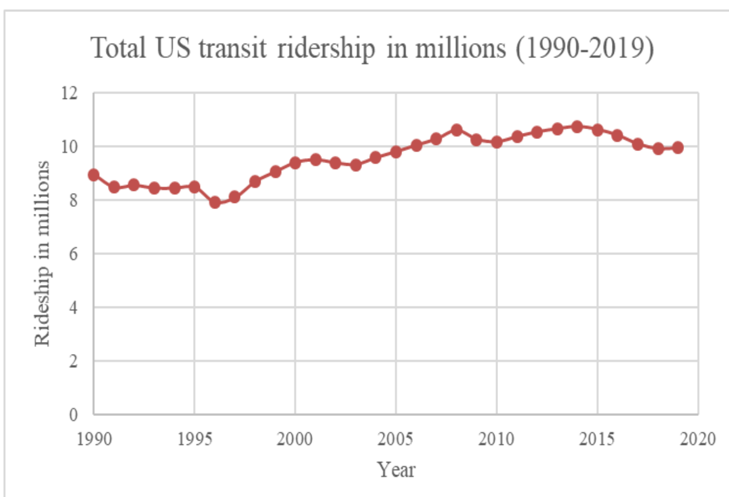


Figure 2 Total ridership in the United States (1990-2019) (Source: APTA, 2019)

The ridership trend has not been reaching the forecasted level. There could be a number of reasons for the negative trend in ridership, with some of them being increasing private car ownership, relatively low gas price, urban sprawl, transit service laybacks, and the rise of taxi/ride services (for example, Uber and Lyft) (Graehler 2019).

Bus transit reliability is one of the most critical service characteristics from a bus transit user perspective. While the level of service and customer satisfaction influence the ridership, the inconvenience, uncertainty in the operations, and added time of unreliable services diminish the transit user confidence and may ultimately result in the overall decline of ridership. In other words, providing reliable bus transit service might foster a more significant, more satisfied, and committed base of bus transit users.

1.2 Problem Statement

Many urban areas face mobility challenges due to an increase in travel demand and resource constraints. Practitioners are exploring other avenues to increase public transportation ridership with economically efficient investment plans to meet the travel demand, reduce congestion, and contribute to sustainability. Despite the ongoing efforts, recent statistics indicate that ridership has decreased in many cities in the United States, and bus ridership alone decreased by 5% in 2017 compared to 2016 (Driscoll et al. 2018).

There is a need to research and identify factors that encourage the use of the bus transit system over other modes of transportation. The availability of transit service, frequency, and transit system reliability are a few factors that affect transit ridership. The perception of transit reliability among users is based on on-time arrival/departure and waiting time (Strathman and Hopper 1993; Nakanishi 1997; Strathman et al. 1999, Bertini and El-Geneidy 2003; Surprenant-Legault and El-Geneidy 2011; Currie and Delbosc 2011; Kathuria et al. 2020). Yet, intra-city bus services often show inconsistencies in on-time arrival/departure at bus stops, thereby influencing ridership. This could be because buses share their travel space with other transportation modes, making them vulnerable to recurrent and non-recurrent congestion. Also, factors like dwelling times, driving behavior, bus characteristics such as age, acceleration and deceleration characteristics, and seasonal variations could affect the on-time arrival/departure at bus stops. The relationships between the on-time performance (OTP) or bus transit reliability and ridership were not explored widely in the past. A clear understanding of the influence of transit reliability on ridership across the region will help develop sound transportation policy decisions for regional transit system management.

Bus transit ridership varies with day of the week, time of the day, and the direction of travel. It also has an effect on dwell times at bus stops and depends on spatial location and the type of bus stop. As traffic congestion, traffic volumes, and travel times depend on these factors, there is a need to examine the association between bus transit reliability and ridership accounting for these factors.

This research, therefore, aims to analyze the relationships between bus transit reliability and ridership by day of the week, time of the day, direction of travel, and type of bus stop. The findings help public transportation agencies effectively utilize available resources, plan, and provide equitable services to all transit system users.

1.3 Research Objectives

This research aims to understand the influence of bus transit reliability on ridership at a bus stop level from a bus transit user perspective. The objectives of this research are:

1. to identify and better understand the bus transit reliability performance measure,
2. to analyze the relationship between bus transit reliability and ridership by the day of the week, time of the day, and direction of travel, and,
3. to research the relationships by bus stop type (for example, transit center, bus stop near an LRT station, transit centers near LRT, etc.).

1.4 Organization of the Thesis

The remainder of the thesis is organized as follows. Chapter 2 presents the review of past studies on transit reliability performance measures and their applicability. A detailed overview of factors affecting transit ridership and reliability is also included in Chapter 2. Chapter 3 outlines the methodological approach used in this research. Chapter 4 provides the discussion on the study area, data collection, and data processing. Chapter 5 summarizes the results from the Pearson correlation analysis between bus transit reliability and ridership. Chapter 6 summarizes the conclusions and limitations of this research and the directions to take this research forward in the future.

CHAPTER 2 LITERATURE REVIEW

This chapter begins with a description of relevant findings from the literature on factors influencing transit ridership, transit reliability performance measures, and the effect of transit reliability on ridership. The review of transit reliability performance measures elaborates OTP, followed by its significance. The limitation of the past studies is also included in this chapter.

2.1 Factors Affecting Transit Ridership

The factors affecting public transit ridership investigated in previous research studies can be classified into external and internal factors. The external factors are not related to the transit system and its operators, such as fuel price, employment, and population. Internal factors include the transit system characteristics like the transit service, quality of service, transit fares, and operating hours.

Descriptive analysis and causal analysis are two widely adopted methodologies in evaluating the factors influencing transit ridership. The attitudes and perceptions are descriptive in nature, and system-related studies are based on causal analysis. The outcomes from the descriptive analysis are generally helpful in transit service planning and policy decisions. In contrast, cause and effect outcomes may benefit travel demand-supply analysis and measuring transit system performance.

Common descriptive analysis studies dealing with the external factors include computer-aided surveys, on-board travel surveys, and use of National Household Travel Survey (NHTS) data to assess public transit travel demand based on factors like population density and housing around transit stops and the influence of advanced traveler information systems (ATIS) on transit ridership (Cervero 1994; Abdel-Aty 2001; Chakrabarti 2017). The causal analysis dealing with the ridership from external factors perspective, on the other hand, seeks to develop explanatory models using population characteristics, regional economy, geographic characteristics, and transportation variables. The exploratory modeling techniques adopted by a few researchers include ordinary least square (OLS) regression and two-stage least square regression (Taylor et al. 2009; Brakewood et al. 2015).

Similarly, descriptive statistics studies focusing on internal factors include on-board surveys based on transit users' attitudes and travel behavior patterns to ultimately understand the influence of variables in the control of transit operators or agencies on transit ridership. These variables include transit fare, bus stop amenities, and transit service quality factors (Syed and Khan 2000; Tirachini et al. 2010; Lai and Chen 2011, Sharaby and Shiftan 2012; Redman et al. 2013; Abenoza 2017). The causal analysis studies focusing on internal factors use data from local transit authorities to assess transit-related factors like transit reliability based on OTP and transit frequency and their influence on transit ridership (Chakrabarti and Giuliano 2015; Gkiotsalitis 2018).

External factors like road characteristics, land use characteristics, socioeconomic characteristics, and demographic characteristics at a transit stop/route/network level also influence transit ridership (Pulugurtha and Agurla 2012; Guerra 2014; Bhattacharjee and Goetz 2016). Other studies that explored the influence of public transportation on land use include developing a framework to identify ridership trends based on land use types like commercial and residential, and amenities like transportation, education, entertainment, etc. The findings from those studies showed a positive association between the ridership and the amenities at the earlier stage of development. However, a reduction in ridership was observed in later stages (Baum-Snow and Kahn 2000; Ishikawa and Tsutsumi 2006; Putman 2013; Hurst and West 2014; Hu et al. 2016; Sun et al. 2016; Li et al. 2016).

Studies have shown empirical evidence that socio-economic characteristics can explain the variation in travel patterns more than land use characteristics (Stead 2001). A few research studies signify that the built environment, like pedestrian-friendly intersections, walk and bike connectivity, safety, etc., at transit stops influences ridership (Khattak and Rodriguez 2005; Kim et al. 2007; Forsyth et al. 2009; Choi et al. 2012; Pulugurtha and Srirangam 2021). A few studies also state that safety and accessibility to bus transit systems play a vital role in increasing transit system usage, which increases ridership (Pulugurtha et al. 1999; Pulugurtha and Vanapalli 2008; Pulugurtha et al. 2011).

Previous studies also documented the effect of internal factors like service reliability, headway, and travel times of the bus-transit service on transit ridership (Van Oort et al. 2015; Ansari Esfeh et al. 2021). Other studies exploring the influence of internal factors like service time, adherence time, and operating time on transit ridership mainly focus on developing a framework to identify ridership trends based on integrating the transit users' and operators' perspectives on transit reliability. The findings from those studies indicated that the improved travel time and service time have positively influenced ridership initially. Later, there is a trend reversal of reduction in ridership with improved service time and travel time (Conway et al. 2017; Coleman et al. 2018).

A few research studies (Hickey 1992; Ting and Schonfeld 2005; Almasi et al. 2016) explored the intermodal effect of public transportation. They mainly focused on the coordination between the LRT services and bus transit services and optimization strategies. The studies on intermodal transit influence stated that the ridership of one transit service may be influenced by the operating times or scheduling times of the other transit services.

2.2 Transit Reliability Performance Measures

Public transit remains one of the most critical parts of the overall transportation system in a region. It promotes sustainability, accessibility and improves the mobility of various population groups (Gershon 2005). Monitoring the performance measures of public transportation has improved since advanced monitoring and tracking systems have been deployed by transit agencies worldwide. The performance measures related to transit reliability are primarily focused on improving ridership, and they help transit agencies assess specific goals identified to improve transit services. The agencies use transit performance measures for service monitoring, economic performance evaluation, internal communications, development of service design standards, communication of achievements and challenges, and community benefits (Ryus 2003).

Past research on bus and LRT ridership suggests that frequency of service influences ridership (Brakewood et al. 2015). Similarly, factors like mixed traffic lanes, bus lanes, median bus-ways on city streets, reserved lanes on freeways, and bus-only roads influence the transit system performance (Levinson et al. 2003). A few studies identified variables such as fares, number of stations, average distance between two stations, average speed, average peak/non-peak headways, and vehicle capacities factors influencing transit system performance (Hensher and Golob, 2008).

Bus transit reliability has been defined in many ways from both user and transit agencies' perspectives. The most widely used of these are OTP and headway adherence

(Strathman and Hopper 1993; Nakanishi 1997; Strathman et al. 1999, Bertini and El-Geneidy 2003; Surprenant-Legault and El-Geneidy 2011; Currie and Delbosc 2011; Saberi et al. 2013; Kathuria et al. 2020). Wong and Khani (2018) proposed a methodology for developing a performance measure for transit reliability by identifying the bus transit delay based on the associated delays with bus facilities at the bus stop level.

Several factors influence transit reliability. In recent years, transit reliability has been considered to be a critical aspect to quantify the service aspects of a system (Currie et al. 2011). It has become an important topic of concern for researchers, transit operators, and users. Transit reliability significantly affects user experience and service quality perceptions. The factors influencing reliability include traffic conditions, road construction, vehicle maintenance and quality, schedule achievability, evenness of passenger demand, operations control strategies, weather, route length and number of stops, differences in operator driving skills, route familiarity, and adherence to schedule (Levinson 2004).

According to the Transit Capacity and Quality of Service Manual (TCQSM) 3rd edition, public transit reliability is one of the measures for transit quality of service (QOS) based on comfort and convenience from a transit user perspective for fixed-route services. The headway adherence, OTP, and excess wait time are the standard reliability measures defined based on the delay caused to transit users due to schedule deviations. The headway adherence is measured based on headway variability. This measure applies to public transit services operating with headways (time difference between successive services) of 10 minutes or less (Diab 2016). Transit users would not consider adherence to the service schedule as transit users experience minimal or no wait time before boarding the next transit service.

The OTP and excess wait time measures are applicable for services operating with headways greater than 10 minutes. The OTP is based on service deviations in actual and scheduled departure times. It is defined as the percent of schedule deviations that fall in the range of 1 minute early up to 5 minutes late. The best OTP service-level identifies on-time percentage within 95 to 100 %, i.e., a transit user making one round trip per weekday with no transfers experiencing one not-on-time vehicle every two weeks. However, certain transit agencies use different ranges to define OTP based on the region-specific operations. Nearly 42% of agencies used a value greater than 5 minutes late for on-time, and 8% used a value greater than 5 minutes early for on-time (TCRP 2003). The excess wait time measure is based on the average of schedule deviations and overall deviation in schedule, but not point-level deviations considered in OTP measurement. Therefore, this research adopts OTP as the measure for bus transit reliability analysis. In this research, it is defined as the difference between scheduled and actual departure times at a given bus stop.

2.3 Significance of Transit Reliability

A few studies investigated the cost of transit quality factors such as crowding, transit frequency, and user information systems on transit reliability (Litman 2008). They proposed a methodology to quantify the cost of transit reliability on transit users using automatic vehicle location (AVL) data, which is considered as high-resolution transit data captured using global positioning system (GPS) technology (Casello et al. 2009). The findings from their research showed that improving transit reliability at a given stop can decrease transit users' generalized costs by 15% in a reasonably reliable network. Benezech and Coulombel (2013) studied the impact of transit frequency and reliability on travel cost and the choice of transit users' departure time.

In general, automated passenger counter (APC) systems are used to collect the transit data. To measure ridership and reliability APC systems paired with AVL technology are used. However, AVL technology is not used by all transit agencies and acquiring this data involves privacy and legality issues. Studies that used APC data include (Patnaik et al. 2004; Wong and Khani 2018). Studies that used data obtained using AVL technology include (Camus et al. 200; Lin et al. 2008; Barabino et al. 2015).

Data analysis of transit reliability-related variables were approached differently in each study, based on the respective study objectives. Research studies in the past developed a set of multivariate regression models to estimate bus arrival time and assist with transit users' decision-making (reduce waiting time due to transit unreliability) at major bus stops along a route in an urban network (Patnaik et al. 2004).

A few studies focused on integrating the transit users' and transit agencies' perspectives on transit reliability and studied the response of transit users to schedule adjustments to improve reliability (Diab et al. 2015). Delgado and Aktas (2016) explored strategies to improve the transit network's reliability resilience by incorporating technologies to withstand harsh weather conditions and upgrading tracks and bridges.

Several researchers have studied transit reliability at stop, route, and network levels. A few studies focused on service reliability based on bus operational characteristics, and the performance measures like punctuality index based on routes (PIR), deviation index based on stops (DIS), and evenness index based on stops (EIS) were proposed (Chen et al.

2009). Duddu et al. (2014; 2019) evaluated transit OTP at a bus stop level based on travel time and delay at previous bus stops.

Jing et al. (2015) explored the effect of uncertainty of a transit vehicle's arrival/departure times and transit users' transfers along a route on transit schedules at a network level. Arhin et al. (2016) examined the factors influencing transit reliability at a bus stop level, such as the number of passengers alighting and boarding, dwell time, and bus stop location with respect to the nearest intersection. Hu and Shalaby (2017) employed regression analysis to determine factors that influence bus reliability and speed at route and segment levels. The results obtained from their study indicated that lower transit reliability and speed are significantly associated with the increase in service distance, signalized intersection density, stop density, volume of boarding and alighting passengers, and traffic volume.

2.4 Transit Reliability on Transit Ridership

The estimation of public transit ridership based on transit reliability is a topic of great interest to practitioners and researchers. Unreliable transit services cause delays to transit users, vehicle crowding, disrupted services, and consequently a negative effect on ridership. This could affect the main aim of several transit agencies to attract car users to transit services.

Recent studies on public transportation stated that reliability and frequency are important public transit factors that attract car users to public transport (Redman et al. 2013). Kashfi et al. (2015) found that the ratio of in-vehicle transit travel time to in-vehicle automobile travel time has a statistically significant negative relationship with transit ridership in Brisbane, Australia. Abate et al. (2013) studied the relationship between reliability and productivity in passenger railroad services in Europe. The findings from their research indicated that increasing reliability improves the productivity of railway operations.

Tyndall (2018) evaluated the increase in bus transit mode share due to the improvements to bus service quality and reliability in New York City, NY. Tang and Thakuriah (2012) evaluated the effect of real-time bus information on the overall ridership of the Chicago Transit Authority (CTA). Their results showed an increase in ridership due to providing real-time information to the transit users.

To increase the transit demand, transit agencies focus on increasing the reliability of transit. This is because unreliable transit services compel transit users to invest more time to make a trip, which often results in longer wait times at transit stops. Uncertainty in planning a transit trip, especially if an en-route transfer is involved, becomes very complicated for a transit user. The chances of reduced transit usage or dependency on alternate modes of transportation are higher in such cases. As a counter-strategy, transit agencies provide transit users with real-time transit location information to be better informed about possible delays and plan their trip efficiently with lower wait times at transit stops.

2.5 Limitations of Past Research

A review of the past literature gives a comprehensive overview of the data collection strategies, variables considered, and research methodologies adopted to identify the relationship among transit reliability, ridership, and factors influencing them. The research methodologies were adopted to estimate the association at different levels (route, city, and county). However, not much was documented based on passenger perspective at bus stop level. The effect of temporal indicators (day of the week, time of the day), spatial indicator (direction of travel), and type of bus stop on the association between bus transit reliability and ridership were not investigated widely in the past. This research attempts to address these limitations (how the association between bus transit reliability on ridership varies according to day of the week, time of the day, type of bus stop, the direction of travel from a transit user perspective at a bus stop level).

CHAPTER 3 METHODOLOGY

This chapter provides an overview of the methodological framework adopted in this research. It includes the following steps.

1. Identifying and estimating the bus transit reliability performance measure
2. Understanding the association between bus transit reliability and ridership by considering temporal (time of the day and day of the week) and spatial (direction of travel) indicators
3. Examining the relationship between bus transit reliability and ridership by the type of bus stop

3.1 Identifying and Estimating the Bus Transit Reliability Performance Measures

Based on the past literature review and data availability, this research considers OTP percentage as the measure of bus transit reliability. The bus transit system considered in this research has headways between services from 20 minutes to 60 minutes for all the periods (morning peak, mid-day, evening peak, and night-time) for both weekdays and weekends. The TCQSM 3rd Edition recommends OTP percentage as a measure of reliability for all bus headways greater than 10 minutes. The Charlotte Area Transit System (CATS) monitors the OTP of the bus service at a bus stop, and the data pertaining to the bus service was collected by CATS.

In general, departure adherence is considered to be critical in calculating the serviceability of the bus transit system (Mahdavilayen et al. 2020). The data provided by

CATS has actual departure time and scheduled time (or scheduled departure time) for the transit service evaluation at each bus stop along with other variables. The departure adherence is computed using Equation 1.

$$Departure\ Adherence = Actual\ Departure\ Time - Scheduled\ \text{Departure}\ Time \qquad (1)$$

The schedule deviation given by the actual departure time minus the scheduled departure time (per one-way trip) is considered as on-time if the outcome lies in the range of -1 minute (early) to +5 or +3 minutes (late). The results beyond this range are considered not on-time or late and contribute to the system's unreliability.

The OTP of a bus service for a given time period is measured as a percentage of the schedule deviations in departures at a bus stop. The deviations are -1 to 5 minutes of the desired time of departure i.e., no more than 1 minute early and up to 5 minutes late (TCQSM 3rd Edition). For example, consider a bus with the scheduled departure time along a given route at a given stop is 6:20 PM. The bus is said to be on-time if it departs between 6:19 PM and 6:25 PM. For passengers alighting the bus, it helps in giving adequate time to plan for their respective destinations and better plan for their transfers during the journey.

Additionally, the percentage of schedule deviations in departures at a bus stop based on -1 to 3 minutes of the desired time of departure was also computed and evaluated in this research.

With the obtained values of departure adherence, the OTP values are computed using the framework shown in Figure 3.

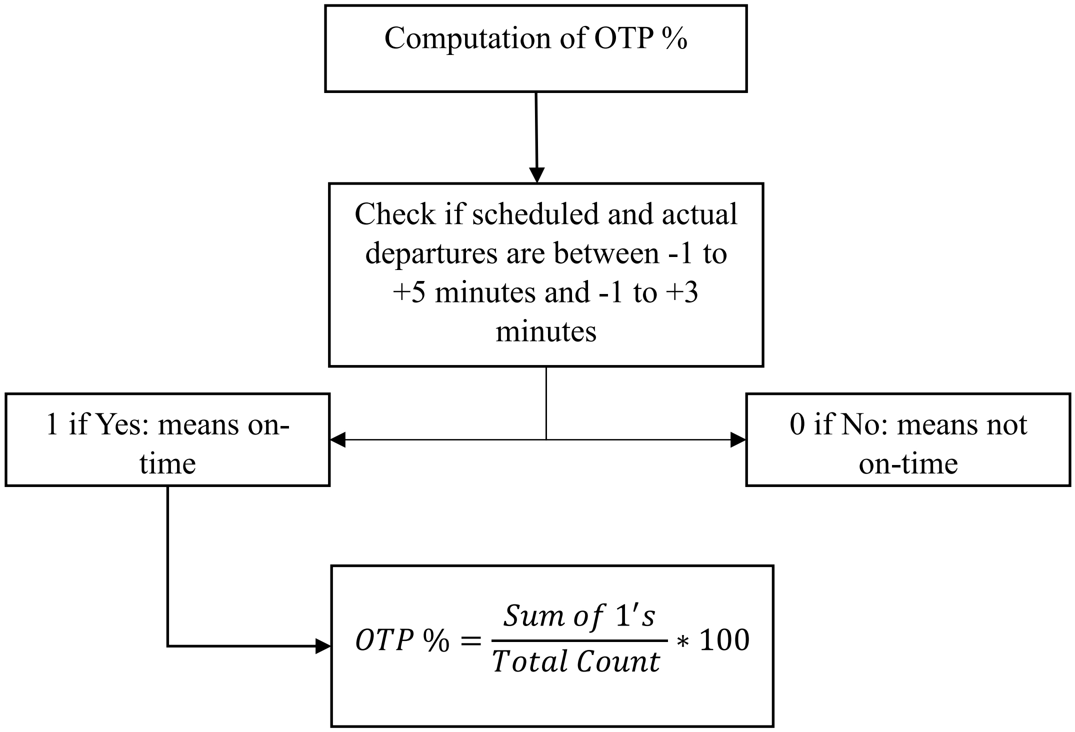


Figure 3 Framework for OTP computation

If the computed departure adherence lies between -1 to +5 minutes and -1 to +3 minutes, then a Boolean value is assigned to it. OTP is computed based on the number of trips on-time divided by the total number of trips. As it is expressed in terms of percentage, it is then multiplied with 100. This OTP percentage is used as the bus transit reliability. It is computed for the bus services by time of the day, day of the week, direction of travel, and type of bus stop separately. The desired values of bus transit reliability are obtained by day of the week, time of the day, and direction of travel by using Equation 2.

$$BTR = \frac{\#\ of\ stop\ level\ trips\ the\ bus\ is\ on\ time\ on\ a\ weekday\ (in\ whole\ year)}{Total\ \#\ of\ stop\ level\ trips\ on\ a\ weekday\ (in\ whole\ year)} * 100 \qquad (2)$$

where BTR is bus transit reliability.

Table 1 describes the bus transit reliability ranges and their interpretation from a transit user perspective and an operator perspective per the TCQSM manual 3rd Edition. For example, if the computed bus transit reliability lies within the considerable threshold of 70% - 79%; the bus is said to be reliably operating during the analysis period.

Table 1 Bus transit reliability expressed as OTP percentages from passenger and operator perspectives (Source: TCQSM 3rd edition)

On-time performance	Passenger perspective	Operator perspective (system-level)
95-100%	• Passenger making one round trip per weekday, with no transfers, experiences one not on-time vehicle every 2 weeks	• Achievable by transit services operating below capacity on a grade separated guideway not shared with non-transit vehicles, with few infrastructure or vehicle problems
90-94%	• Passenger making one round trip per weekday, with no transfers, experiences one not-on time vehicles every week	• Achievable by transit services operating on a grade separated guideway not shared with non-transit vehicles
80-89%	• Passenger making one round trip per weekday, with no transfers, experiences up to two not-on-time vehicles every week	• Typical range for commuter rail that shares track with freight rail • Typical range for LRT with some street running • Achievable by bus services in small-to mid-sized cities
70-79%	• Passenger making one round trip per weekday, with no transfers, experiences up to three not-on-time vehicles every week • Passenger making one round trip per weekday, with transfers, experiences a not-on-time vehicle every day	• Typical range for LRT with a majority of street running • Achievable by bus services in large cities
<70%	• Service likely to be perceived as highly unreliable	• May be best possible result for mixed traffic operations in congested central business districts

From Table 1, 70% – 79% is considered achievable for large cities, i.e., a transit user making one round trip per weekday, with no transfers, experiences three not-on-time services every week. The considered study area falls the under the category of large city. Hence, this range is considered as a threshold for bus transit reliability in this research.

It is important to note that, as specific data related to trips involving transfers are not available, all trips are assumed to be unlinked in this research. Bus transit reliability computation involves the daily on-time performance of the transit (which means the computation of bus transit reliability mainly focuses on daily performance consistently). Thus, the basic unit of bus transit reliability is based on the number of days of the week present in the time period. In other words, bus transit reliability is computed based on the combined scheduled deviations and departure times of a bus at bus stop for all days of the week considered in the analysis period by considering a typical weekday/weekend. The bus transit reliability computed for 1 minute early 5 minutes late (-1 to +5 min) and 1 minute early and 3 minutes late (-1 to +3 min) are 'BTR (-1 to +5 min)' and 'BTR (-1 to +3 min)' in the tables. As stated previously, the computed bus transit reliability measures with reference to departure are expressed in percentages.

3.2 Understanding the Association between Bus Transit Reliability and Ridership by Considering Temporal and Spatial Indicators

A two-fold analysis was conducted to understand the relationship between bus transit reliability and ridership and its temporal and spatial variations in the study area. Day of the week and time of the day are considered as temporal indicators, and the data are grouped accordingly. Later, the grouped data in the first step is arranged based on the direction of travel as a spatial indicator. The two steps are done to better understand the association between transit reliability and ridership more clearly.

The Pearson correlation analysis was performed to identify the linear relationship between transit reliability and ridership. Primarily, a typical weekday (Wednesday) and weekend (Sunday) are considered as day of the week for the entire study period (for a year) throughout the entire research. The individual 52 weeks (as the study period is for a year) of data for the considered day of the week are collected and used for the analysis. The OTP (bus transit reliability in this research) are computed separately for each dataset, along with the ridership values.

The next level of analysis was conducted by considering the time of the day. A total of four hours of the day were considered based on the trip start time (morning peak hour: 7:00 AM - 9:00 AM, mid-day hour: 12:00 PM - 2:00 PM, evening peak hour: 5:00 PM - 7:00 PM, and night-time hour: 8:00 PM - 10:00 PM). Similar datasets were prepared for the analysis by considering all the bus services under the selected time of the day for the entire year. A total of 8 datasets were formed for both the weekdays and weekends. The Pearson correlation analysis was performed for the considered time of the day for that particular day of the week separately.

Inbound and outbound are the two types of directions of travel present in the dataset. Pearson correlation analysis is conducted separately for both the inbound and outbound trips of the bus service. A total of 16 datasets were developed for both weekday and weekend and are used for the analysis. The Pearson correlation coefficient that fell within a 95% confidence level was identified.

3.3 Understanding the Relationship between Bus Transit Reliability on Ridership Based on the Type of Bus Stop

The association between bus transit reliability and ridership varies temporally for the entire study period. The considered study area in this research has LRT and bus transit as major public transportation services operating in the city. With the presence of another transit service facility nearby (in this case, LRT), it is believed that ridership of one may be affected by the other (Hickey 1992; Ting and Schonfeld 2005; Almasi et al. 2016). Hence, it is believed that exploring the type of bus stop or type of facility existing near the vicinity of the bus transit network may add an advantage to the research. The collected data shows a variation of ridership in a high-activity bus stop (bus stop located in the downtown area) than a normal bus stop (bus stop located in the suburban area). Exploring the association between bus transit reliability and ridership by considering the type of bus stop will help understand the association at a granular level. The bus stops considered in this research belong to the following categories (description shown in Table 2).

- Normal bus stops: the bus stops which show consistent trends in ridership and are located far away from the LRT station
- LRT related bus stops: Bus stops located in the vicinity of walking distance from an LRT station
- Transit centers: Bus stops with high activity of transit ridership values; also, considered as the bus stops for transfers

Table 2 Description of type of bus stop

Type of bus stop	Description
All bus stops near LRT stations	Bus stops within a 0.25-mile buffer from each LRT station
LRT related transit centers	Transit centers that lie within a 0.25-mile buffer generated from each LRT station
Other transit centers	Transit centers that are not near LRT stations
Bus stops near LRT stations	All bus stops which are not transit centers which lies within a 0.25-mile buffer generated from each LRT station
Other bus stops	Bus stops which are not near LRT nor a transit center

To categorize the list of bus stops, primarily the bus stops near LRT were identified by generating a 0.25-mile buffer from each LRT station. A 0.25-mile buffer is typically considered as standard walk distance to access a bus stop (Aultman-Hall et al. 1947; Pulugurtha and Agurla 2012; Chakrabarti 2015). The bus stops that fell within the 0.25-mile buffer of an LRT station are identified as LRT related bus stops. There are normal bus stops as well as transit centers under the category LRT related bus stops. The details about the transit centers were mentioned in the stop description of the bus stop. The remaining stops were considered normal bus stops.

The processed data have transit centers operating in the local bus service routes in the urban area. Transit centers are high activity bus stops located in the city's downtown area, which is a major stop for transferring passengers to their destinations. As these stops are located in the downtown areas, usually, high passenger activity is expected. However, the ridership pattern may not always stay high for all times of the day and days of the week. There may be high ridership activity over the weekday and a decrease on the weekend. Similarly, there may be high activity in the morning peak and low activity in the afternoon or night-time. To better understand the temporal variations pertaining to the bus stop type, the data related to the transit centers were analyzed separately.

CHAPTER 4 STUDY AREA AND DATA

This chapter provides an overview of the study area, data collection, data processing, and variables considered in this research.

4.1 Study Area and Data Collection

The city of Charlotte, one of the most populated cities and commercial hubs in North Carolina, was chosen as the study area for this research. Charlotte is located in the Piedmont region of North Carolina. The population was ~1 million as of the 2020 census, with a growth rate of around 1.9% per annum as of 2018 (NCDOT 2020). Charlotte Area Transit System (CATS) is the agency responsible for public transportation in Charlotte. The public transportation system of the city includes bus and LRT. This research focuses only on bus transit system within the city limits. Figure 4 shows the study area considered for this research.

The data for this research was obtained from CATS for the year 2017. There were 76 fixed bus transit service routes in the entire city. Out of these, 49 are local bus service routes, 18 are express bus service routes, and 9 are neighborhood bus service routes. There are a total of 2,933 bus stops in the city that serve all bus service types by CATS. One-way bus fare for an adult is around $2.20. The majority of the local bus routes are connected to/from the city's downtown/uptown and popular LRT stations. The city's downtown/uptown is where most of the business is located, and most work-related trips are observed to and from downtown/uptown.

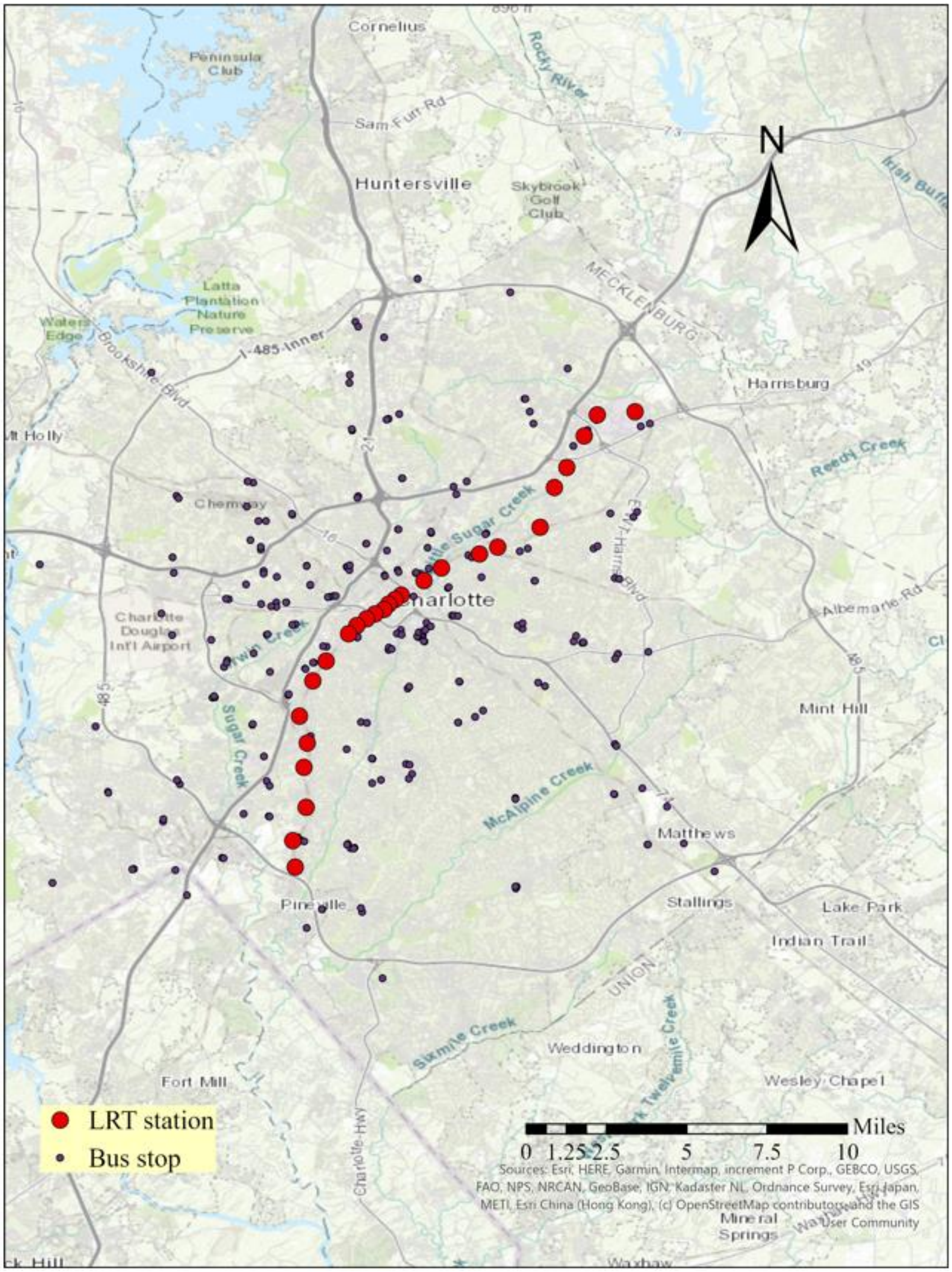


Figure 4 Study area

A total of 49 local bus service routes are considered for analysis in this research, as they constitute the majority of connections within the city. The express routes were not considered in this research as they have a fewer number of stops when compared to local routes of bus service; thereby, they decrease the number of records in both ridership and reliability data.

The transit data collected from CATS have reliability data and ridership data for all the bus stops (401 bus stops) in the city. Of these, 394 bus stops were considered for analysis due to the data availability (available for all 52 weeks in a year). As the analysis is for a year, it is made sure that all the 52 weeks of the reliability data and ridership data are available for the considered bus stops for analysis.

4.2 Data Processing

Data was processed in two steps. The first step involved identifying important bus transit reliability and ridership details for a typical weekday and weekend. The second step involved the preparation of an integrated database by processing the bus transit reliability and ridership data. The bus transit reliability and ridership data were processed using Python Pandas, and the type of bus stop was identified using ArcGIS platform.

4.2.1 Transit Reliability Data and Ridership Data

Bus transit reliability data for a given bus stop includes the actual arrival time, actual departure time, scheduled time, direction of travel, route number, service day, stop description, date, time of the day, trip start time, time, and geographical coordinates.

The bus transit ridership at a given stop includes the variables such as route number, direction of travel, stop description, boarding, alighting, date, trip start time, geographical coordinates, departure time, day of the week, and time of the day. The variables considered for the analysis are summarized in Table 3.

Table 3 Description of bus transit reliability and ridership variables

Transit Reliability Data		
S No	**Variables**	**Description**
1	Actual arrival time	Time point arrival in seconds past midnight (time measured from mid-night)
2	Actual departure time	Time point departure in seconds past midnight (time measured from mid-night)
3	Scheduled time	Scheduled time in seconds past midnight (time measured from mid-night)
4	Direction of travel	Direction of travel (Inbound, Outbound, North, South, East, West)
5	Route number	Different numbers for each local bus route, express route, neighborhood bus route, and community bus route
6	Day of the week	Weekday, Sunday, Saturday
7	Stop description	Name of the bus stop
8	Date	Date in yyyy/mm/dd format
9	Time of the day	Morning peak, mid-day, evening peak, night-time
10	Trip start time	Start time of trip with respect to 24:00:00
11	Latitude	Geographic coordinates of the bus stop
12	Longitude	
Transit Ridership Data		
S No	Field	Description
1	Route #	Different numbers for each local bus route, express route, neighborhood bus route, and community bus route
2	Direction of travel	Inbound, Outbound, North, South, East, West
3	Stop description	Name of the bus stop
4	Boarding	Number of passengers boarding the bus
5	Alighting	Number of passengers alighting the bus
6	Date	Date in yyyy/mm/dd format
7	Trip start time	Start time of trip with respect to 24:00:00
8	Latitude	Geographic coordinates of a bus stop
9	Longitude	
10	Departure time	Time point departure in seconds past midnight (time measured from mid-night)
11	Day of the week	Weekday, Sunday, Saturday
12	Time of the day	Morning peak, mid-day, evening peak, night-time

4.2.2 Preparation of the Integrated Database

The bus transit reliability and the ridership data were processed individually to identify the necessary variables for the analysis. The process of preparing an integrated database is shown in Figure 5. To develop an integrated database, the common and unique variables in both the bus transit reliability and ridership data were used as the matching fields. They are route number, direction of travel, and stop description.

The route number is a unique number assigned to each local bus route in the city limits. Similarly, stop description is the name of the bus stop serving a local route. The direction of travel describes the direction of the trip, which can either be inbound, outbound, North, South, East, and West in the city. The stop description and the route number are used to integrate the database because a route could have multiple bus stops. To capture the data for all the bus stops in the route, both route number and stop description are used as matching fields.

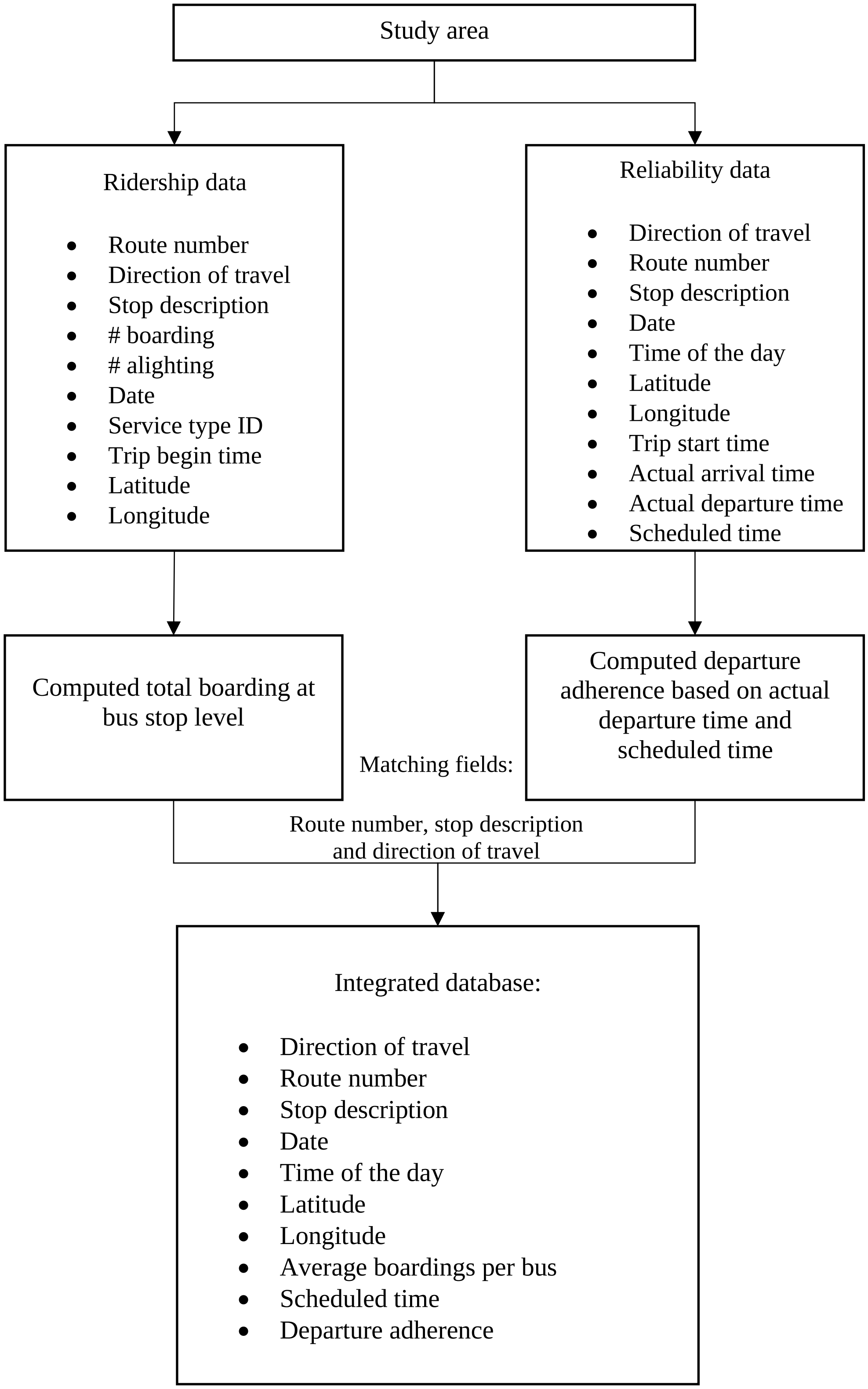


Figure 5 Data integration framework

The integrated database consists of the variables such as direction of travel, route number, stop description, date, time of the day, latitude, longitude, average number of boardings per bus, average number of alightings per bus, and bus transit reliability measures [(-1 to +5 min) and (-1 to +3 min)].

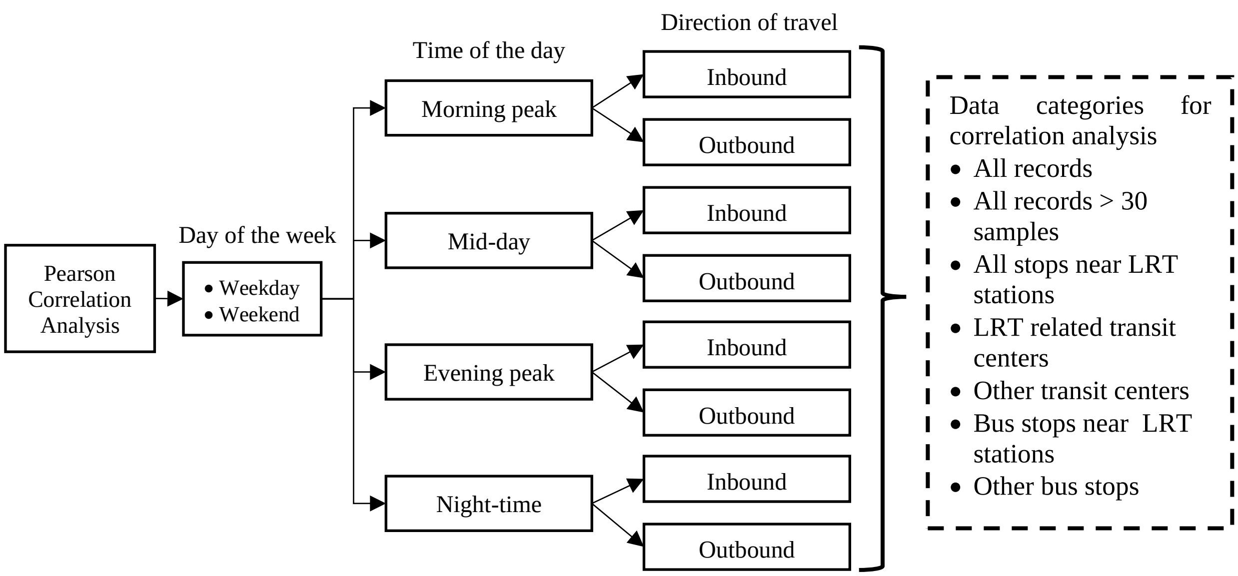
The direction of travel which is mentioned as one of the variables in the database, has two types of direction: inbound and outbound. The inbound bus stops serve the trips to the City Transit Center (CTC) located in the downtown/uptown from the suburbs, and the outbound bus stops serve the trips from the CTC to the suburbs. North, South, East, and West bus stops serve trips to/from transit centers in specified directions of the city. The obtained database has 181 inbound bus stops, 175 outbound bus stops, 13 North direction bus stops, 15 South direction bus stops, 5 East direction bus stops, and 5 West direction bus stops. As there are no sufficient samples in North, South, East, and West directions for a separate analysis (a total of 38 samples), they are also classified as inbound and outbound based on their reference with geographical North. If the bus is due North and leaving towards the transit center, it is considered as an outbound bus stop. A similar logic was followed for the rest of the directions to classify them as inbound and outbound bus stops.

The processed data is used to compute the bus transit reliability and ridership at the bus stop level. The actual departure time and scheduled time are used to compute departure adherence. This is used in the computation of bus transit reliability (OTP in this research).

The final integrated database is then used for the analysis, which involves arranging data by day of the week, time of the day, direction of travel, type of bus stop, and conducting the Pearson correlation analysis.

CHAPTER 5 RESULTS

This chapter includes descriptive statistics of data and Pearson correlation analysis results. The Pearson correlation analysis was performed to understand the association between bus transit reliability and ridership. Further, the association between bus transit reliability and ridership is analyzed by considering spatiotemporal indicators and the type of bus stop. Figure 6 shows the classification of Pearson correlation analysis after the segregation of data.



Note: The data classification for Pearson correlation analysis was performed after the data was segregated based on time of the day, day of the week and direction of travel

Figure 6 Data classification for Pearson correlation analysis

The bus transit reliability for each individual bus stop are computed based on the service frequency at the bus stop. The Pearson correlation analysis was conducted in a total of five stages based on the data segregation. A total of 182 correlation tables were developed and examined. The processed data was analyzed by segregating the data by day of the week, time of the day, direction of travel, and type of bus stop.

A typical weekday (Wednesday) and weekend (Sunday) are considered for the analysis by day of the week. A total of four times of the day are considered and filtered based on the trip start time (morning peak: 7:00 AM - 9:00 AM, mid-day: 12:00 PM - 2:00 PM, evening peak: 5:00 PM - 7:00 PM and night-time: 8:00 PM - 10:00 PM) for analysis by time of the day. Inbound and outbound are the two directions considered as spatial indicators for the analysis by the direction of travel. Inbound direction trips are from sub-urban areas to CTC, whereas outbound trips are from CTC to sub-urban areas.

Previous literature states that the presence of intermodal transit services within a city influence the ridership throughout the city. The coordination in the operational services of the transit (bus transit and light rail transit) may account for the variation of ridership. In an attempt to fill the research gap (examining the association between bus transit reliability and ridership at bus stop level), bus stops are classified based on the ridership activity. The selected bus stops for this research are geospatially distributed over the study area.

5.1 Descriptive Statistics of the Bus Transit Reliability and Ridership

A descriptive analysis was conducted to identify possible outliers and anomalies in the data. The minimum, median, mean, maximum, and standard deviation of bus transit reliability and ridership were computed and examined. Table 4 summarizes the descriptive statistics of the considered bus transit reliability and ridership by day of the week and time of the day. Additional tables summarizing descriptive statistics by direction of travel and type of bus stop are presented in Appendix A.

Table 4 Descriptive statistics of bus transit reliability and ridership

Time of the day	Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
		Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
All data	BTR (-1 to 5 min)	9.84	13.07	78.70	80.82	74.70	76.32	100.00	96.97	14.93	15.1916
	BTR (-1 to 3 min)	1.60	11.57	59.44	61.16	58.34	59.57	90.38	90.91	15.12	16.1803
	Average # of boardings/bus	0.00	0.00	1.00	0.88	2.10	2.07	22.30	25.89	3.50	3.50799
All data > 30 reco	BTR (-1 to 5 min)	9.85	13.07	78.75	80.96	74.76	76.20	100.00	96.97	14.94	15.4376
	BTR (-1 to 3 min)	1.57	11.57	59.63	61.05	58.42	59.54	90.38	90.91	15.14	16.2843
	Average # of boardings/bus	0.00	0.00	0.95	0.92	2.09	2.14	22.32	25.89	3.54	3.58314
Morning peak	BTR (-1 to 5 min)	5.94	2	77.8	86	74.13	77.84	98.99	97.93	16.95	21.6
	BTR (-1 to 3 min)	3.9	2	56.91	66.45	56.2	63.26	94.67	96.7	17.72	21.45
	Average # of boardings/bus	0	0	0.73	1	2.22	2.59	25.64	23.33	4.01	4.14
Mid-day	BTR (-1 to 5 min)	5.62	7.89	81.91	77.55	77.33	72.89	100	96.94	17.08	18.19
	BTR (-1 to 3 min)	3.78	5.79	62.57	55.99	61.26	55.23	95.92	94.9	18.1	19.46
	Average # of boardings/bus	0	0	1.13	1.3	2.47	2.64	24.08	23.29	4.32	4.01
Evening peak	BTR (-1 to 5 min)	45.44	6	80.51	76.61	76.72	72.71	93.19	97.22	13.52	15.68
	BTR (-1 to 3 min)	30.12	6	59.35	57.15	61.01	55.16	83.75	91.61	14.79	17.39
	Average # of boardings/bus	0	0	1.69	0.93	2.36	2.99	12.78	33.39	2.93	5.26
Night-time	BTR (-1 to 5 min)	3.21	20.19	82.37	77.93	77.37	73.96	97.83	99.5	16.98	16.8
	BTR (-1 to 3 min)	1.6	7.69	62.31	56.2	60	56.32	94.63	95.54	17.33	19.3
	Average # of boardings/bus	0	0	1.15	1.06	2.54	2.73	23.28	27.39	4.38	4.55

Note: BTR is bus transit reliability

Bus stops with greater than 30 records were considered for further analysis. The mean value of bus transit reliability (-1 to 5 min) is about 74% to 76% and the mean value of bus transit reliability (-1 to 3 min) is about 56 to 58%. This indicates that the data of bus transit reliability (-1 to 3 min) is closer to normal distribution than that of bus transit reliability (-1 to 5 min). The normality test was performed with bus transit reliability (-1 to 5 min), bus transit reliability (- 1 to +3 min) and average number of boardings.

A sample normal distribution diagram (for weekday morning peak hour) is shown in Figure 7. The histograms for bus transit reliability (-1 to 5 min), bus transit reliability (-1 to 3 min), and average number of boardings by day of week, time of day, and direction of travel are presented in Appendix B. The x-axis in the histogram represents the value of the variable while the y-axis represents the density curve. It shows the units that make the total area of all the bars equal to 1. The y-axis of a histogram shows how frequently the values on the x-axis occur in the data. Here, x-axis is the value of bus transit reliability (-1 to 3 min) and the y-axis is number of times the values of bus transit reliability (-1 to 3 min) occur in the morning peak hour data considered for a typical weekday. The histogram plot indicates that the data may be normally distributed.

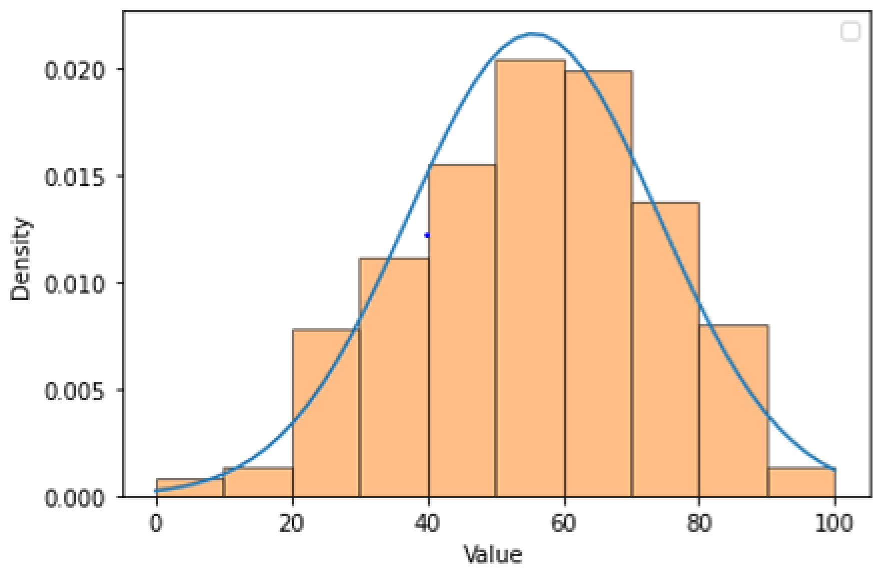


Figure 7 Sample normal distribution diagram for morning peak hour data for a typical weekday

A normality test was performed to examine whether the data is normally distributed or not. The D' Agostino's Pearson K^2 Test was conducted to determine if the data distribution departs from the normal distribution (D'Agostino 2017, Albassam et al. 2021). The test results in summary statistics like the skewness and kurtosis. Skewness is a quantification of asymmetry in the distribution whereas kurtosis quantifies the distribution in the tail. The D'Agostino's Pearson K^2 test was implemented using the SciPy library in

Python. The output of the test is the p-value which is compared to the alpha (0.05 in this case). The null hypothesis is defined as the data is normally distributed. If the p-value is greater than the alpha then the null hypothesis that the data is normally distributed is accepted. Table 5 summarizes the D'Agostino's Pearson K^2 test results for normality.

Table 5 Normality test results

Data classification		Variable	Weekday			Weekend		
			Statistic	P-value	Null Hypothesis	Statistic	P-value	Null Hypothesis
All data		BTR (-1 to 5 min)	17.67	0.00	Rejected	32.09	0.00	Rejected
		BTR (-1 to 3 min)	5.12	0.08	Accepted	9.47	0.01	Rejected
		Average # of boardings/bus	36.10	0.00	Rejected	31.60	0.00	Rejected
Morning peak		BTR (-1 to 5 min)	23.44	0.00	Rejected	44.02	0.00	Rejected
		BTR (-1 to 3 min)	3.73	0.16	Accepted	7.85	0.17	Accepted
		Average # of boardings/bus	25.81	0.00	Rejected	25.91	0.00	Rejected
Mid-day		BTR (-1 to 5 min)	24.29	0.00	Rejected	16.11	0.00	Rejected
		BTR (-1 to 3 min)	5.96	0.05	Accepted	3.47	0.18	Accepted
		Average # of boardings/bus	44.64	0.00	Rejected	14.28	0.00	Rejected
Evening peak		BTR (-1 to 5 min)	8.12	0.12	Accepted	14.50	0.00	Rejected
		BTR (-1 to 3 min)	6.97	0.03	Rejected	3.76	0.15	Accepted
		Average # of boardings/bus	38.67	0.00	Rejected	35.66	0.00	Rejected
Night-time		BTR (-1 to 5 min)	16.94	0.00	Rejected	9.63	0.01	Rejected
		BTR (-1 to 3 min)	2.75	0.25	Accepted	5.90	0.05	Accepted
		Average # of boardings/bus	14.81	0.00	Rejected	17.56	0.00	Rejected
Morning peak	Inbound	BTR (-1 to 5 min)	17.19	0.00	Rejected	31.07	0.00	Rejected
		BTR (-1 to 3 min)	4.53	0.10	Accepted	6.74	0.03	Rejected
		Average # of boardings/bus	5.17	0.08	Accepted	5.96	0.05	Accepted
	Outbound	BTR (-1 to 5 min)	3.76	0.15	Accepted	16.28	0.00	Rejected
		BTR (-1 to 3 min)	0.68	0.71	Accepted	3.19	0.20	Accepted
		Average # of boardings/bus	71.56	0.00	Rejected	23.11	0.00	Rejected
Mid-day	Inbound	BTR (-1 to 5 min)	24.30	0.00	Rejected	10.93	0.00	Rejected
		BTR (-1 to 3 min)	8.76	0.59	Accepted	4.90	0.09	Accepted
		Average # of boardings/bus	15.72	0.00	Rejected	2.84	0.24	Accepted
	Outbound	BTR (-1 to 5 min)	11.19	0.00	Rejected	6.67	0.04	Rejected
		BTR (-1 to 3 min)	2.55	0.28	Accepted	0.22	0.90	Accepted
		Average # of boardings/bus	41.99	0.00	Rejected	29.25	0.00	Rejected
Evening peak	Inbound	BTR (-1 to 5 min)	8.13	0.02	Rejected	22.34	0.00	Rejected
		BTR (-1 to 3 min)	4.52	0.10	Accepted	3.85	0.15	Accepted
		Average # of boardings/bus	4.98	0.08	Accepted	63.40	0.00	Rejected
	Outbound	BTR (-1 to 5 min)	4.68	0.10	Accepted	3.69	0.16	Accepted
		BTR (-1 to 3 min)	3.61	0.16	Accepted	1.11	0.57	Accepted
		Average # of boardings/bus	70.19	0.00	Rejected	40.24	0.00	Rejected
Night-time	Inbound	BTR (-1 to 5 min)	14.83	0.00	Rejected	8.68	0.01	Rejected
		BTR (-1 to 3 min)	3.83	0.15	Accepted	15.00	0.00	Rejected
		Average # of boardings/bus	0.14	0.93	Accepted	27.62	0.00	Rejected
	Outbound	BTR (-1 to 5 min)	10.41	0.01	Rejected	2.71	0.26	Accepted
		BTR (-1 to 3 min)	2.24	0.33	Accepted	0.51	0.77	Accepted
		Average # of boardings/bus	31.79	0.00	Rejected	27.52	0.00	Rejected

BTR is bus transit reliability

5.2 Examining the Association Between bus Transit Reliability and Ridership

To examine the association between bus transit reliability and ridership, the data is arranged based on the computed bus transit reliability and its corresponding ridership for all the bus stops. Table 6 summarizes bus transit reliability and ridership at ten selected bus stops.

Table 6 Bus transit reliability and ridership at selected bus stops

S. No.	Transit bus-service	BTR (-1 to 5 min)	BTR (-1 to 3 min)	Average # of boardings/bus
1	10_Inbound_New Renaissance Way & Burnette Ave	88.29	75.82	2.00
2	10_Inbound_Transit Center- 4th & Brevard	9.85	7.80	0.01
3	10_Inbound_West Blvd & Camden Rd	90.05	79.88	0.52
4	10_Inbound_West Blvd & Remount Rd	90.12	77.01	1.68
5	10_Outbound_East Blvd & Camden Rd	72.86	30.12	2.25
6	10_Outbound_New Renaissance Way & Burnette Ave	68.02	53.00	0.00
7	10_Outbound_Transit Center- Bay G	86.87	58.30	11.12
8	10_Outbound_West Blvd & Remount Rd	81.52	54.98	0.44
9	11_Inbound_Amtrak Station	69.44	29.17	3.80
10	11_Inbound_Transit Center- Bay A	56.32	41.54	0.09

Note: BTR is bus transit reliability

The correlation coefficients, which are significant at a 95% confidence level, are used in the analysis. All the records based on greater than 30 samples were used in the Pearson correlation analysis. This is because a minimum sample size of at least 30 or greater than 30 is required for validity and making statistically significant interpretations. In other words, datasets which are segregated based on day of week, time of day, direction of travel and type of bus stop with at least 30 records are used to perform Pearson correlation analysis.

5.2.1 Association Between Bus Transit Reliability and Ridership considering Temporal and Spatial Indicators

Pearson correlation coefficients were first computed by the day of the week to understand the effect of bus transit reliability on ridership for a typical weekday and weekend. The Pearson correlation analysis results are summarized in Table 7.

Table 7 Association between bus transit reliability and ridership by day of the week

Day of the week	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	0.30	0.23
Weekend	0.27	0.23

Note 1: BTR is bus transit reliability

The results from Table 7 show that there exists a low positive correlation between the average number of boardings per bus and bus transit reliability based on bus transit reliability (-1 to 5 min) and bus transit reliability (-1 to 3min) on weekdays and weekends. This indicates that an increase in bus transit reliability increases the ridership. It can be interpreted from the results that from a transit user perspective, as long as a bus departs on time, the transit users boarding the bus will increase.

The data was further filtered by time of the day to better understand and analyze the association between bus transit reliability and ridership. From the descriptive analysis, the ridership was observed to vary by the day of the week and the time of the day. Performing correlation analysis considering the time of the day may help understand the association between transit reliability and ridership at a more granular level.

Table 8 Association between bus transit reliability and ridership by day of the week and time of the day

Day of the week	Time of the day	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	Morning peak	0.31	0.26
	Mid-day	0.29	0.2
	Evening peak	0.3	0.18
	Night-time	0.31	0.24
Weekend	Morning peak	0.33	0.3
	Mid-day	0.39	0.35
	Evening peak	0.31	0.25
	Night-time	0.32	0.27

Note 1: BTR is bus transit reliability

From Table 8, there exists a moderately positive correlation between the bus transit reliability and the average number boardings during the morning peak and night time hours on a weekday. A low positive correlation was observed for the mid-day and evening peak hours. From a transit user perspective, the correlation is moderately positive in the morning peak hour and night-time hours due to the concentrated number of work trips on the weekdays.

For the weekend, the correlation remains to be moderately positive for all the selected hours of the day. This change in the association between bus transit reliability and ridership can be attributed to various types of trips (recreational trips and shopping trips) over the weekend (as these trips are not time defined, the same kind of correlation exists for all the selected hours of the day). The Pearson correlation analysis based on time of the day and day of the week indicates a statistically significant relationship between bus transit reliability and ridership at 95% confidence level.

Table 9 shows the correlation analysis results for data segregated based on day of the week, time of the day, and the direction of travel.

Table 9 Association between bus transit reliability and ridership by day of the week, time of the day, and direction of travel

Day of the week	Time of the day	Direction of travel	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	Morning Peak	Inbound	0.57	0.56
		Outbound	0.35	0.31
	Mid-day	Inbound	0.52	0.46
		Outbound	0.36	0.26
	Evening Peak	Inbound	0.5	0.43
		Outbound	0.45	0.32
	Night-time	Inbound	0.53	0.48
		Outbound	0.37	0.31
Weekend	Morning Peak	Inbound	0.52	0.39
		Outbound	0.35	0.34
	Mid-day	Inbound	0.46	0.3
		Outbound	0.48	0.49
	Evening Peak	Inbound	0.38	0.29
		Outbound	0.37	0.33
	Night-time	Inbound	0.39	0.31
		Outbound	0.41	0.37

Note 1: BTR is bus transit reliability

From Table 9, it can be observed that the correlation is stronger in the inbound direction during the morning peak, mid-day, and night-time hours than the analysis conducted based on day of the week and time of the day (moderately positive (MP) to high positive (HP)). This can be due to the increase in the transit demand on a weekday regular operating work hour, which results in more inbound trips when the bus service is reliable. In addition, commercial and office (such as business parks and technological hubs) land use developments are concentrated near the central business district part resulting in an increased transit ridership during morning and evening peak hours. The transit ridership for inbound direction is significant during morning peak and night-time hours due to the work-based trip patterns.

The average number of boarding's per bus consistently is moderately and positively correlated with the bus transit reliability based on bus transit reliability (-1 to +5 min) and bus transit reliability (-1 to +3 min) on a typical weekend potentially due to the recreational trip patterns.

Overall, the results show a significant positive correlation between bus transit reliability and ridership for all the times of the day and days of the week.

5.2.2 Association Between Reliability and Ridership based on the Type of Bus Stop

The correlation results considering the temporal analysis indicated a statistically significant relationship between bus transit reliability and ridership. Table 10 shows the Pearson correlation analysis results for data segregated based on day of the week and type of bus stop.

Table 10 Association between bus transit reliability and ridership by day of the week and the type of bus stop

Day of the week	Type of bus stop	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	All bus stops near LRT Stations	0.54	0.44
	LRT related transit centers	0.79	0.75
	Bus stops near LRT stations	0.53	0.48
	Other bus stops	0.37	0.37
Weekend	All bus stops near LRT Stations	0.51	0.46
	LRT related transit centers	0.79	0.78
	Bus stops near LRT stations		
	Other bus stops	0.31	0.26

Note 1: BTR is bus transit reliability
Note 2: Blank cells indicate that the correlation coefficient is not significant at a 95% confidence level

All the bus stops near LRT have high ridership activity. Transit centers in each dataset are generally less in number (45~50 in each dataset). When segregated as LRT-related and not (other transit centers), the sample size becomes statistically insignificant (less than 30) for other transit centers. Hence, other transit centers are not analyzed separately. Primarily, the analysis was conducted by considering each type of bus stop based on day of the week.

From Table 10, it is observed that there exists a high positive correlation between the transit reliability and ridership at all bus stops located near LRT station. This is because of the increased ridership activity near the LRT stations. The bus stops near these LRT stations act as feeder bus stops resulting in increased ridership. A moderate positive correlation exists between the other bus stops and reliability measures considered in this research. The other bus stops located farther away from the LRT stations generally have common bus stop characteristics. Owing to this, the correlation values for other bus stops did not change notably.

Further, a Pearson correlation analysis was performed by considering the four selected hours of the day. Table 11 shows the results from Pearson correlation analysis for data segregated by day of the week, time of the day, and the type of bus stop.

From Table 11, there is a high positive correlation between bus transit reliability and ridership for the bus stops near LRT stations in all the selected hours of the day. On a typical weekday, high positive correlation was observed potentially due to consistent work trips and high ridership at bus stops near LRT. These bus stops serve as feeder routes to the LRT. The bus transit and LRT services may operate in coordination, which requires accurate bus transit reliability.

The transit centers near LRT serve as transfer points on a large scale. The results indicate moderate to high positive correlation for all the times of the day and days of the week. The results indicate that other bus stops near LRT stations indicate low to moderate positive correlation between the transit reliability and ridership for all the times of the day and days of the week. Bus stops located away from the LRT stations may not have exclusive coordination with the light rail. From a transit user perspective, passengers who tend to board the bus at other bus stops may not have any LRT trips.

Table 11 Association between bus transit reliability and ridership by day of the week, time of the day, and the type of bus stop

Day of the week	Time of the day	Type of bus stop	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	Morning peak	All bus stops near LRT stations	0.54	0.46
		LRT related transit centers	0.73	0.69
		Bus stops near LRT stations	0.5	0.4
		Other bus stops	0.44	0.47
	Mid-day	All bus stops near LRT stations	0.58	0.47
		LRT related transit centers	0.79	0.75
		Bus stops near LRT stations	0.59	0.53
		Other bus stops	0.42	0.36
	Evening peak	All bus stops near LRT stations	0.56	0.45
		LRT related transit centers	0.79	0.75
		Bus stops near LRT stations	0.56	0.51
		Other bus stops	0.29	0.17
	Night-time	All bus stops near LRT stations	0.59	0.48
		LRT related transit centers	0.79	0.75
		Bus stops near LRT stations	0.58	0.49
		Other bus stops	0.43	0.41
Weekend	Morning peak	All bus stops near LRT stations	0.53	0.5
		LRT related transit centers	0.74	0.72
		Other bus stops	0.37	0.3
	Mid-day	All bus stops near LRT stations	0.63	0.59
		LRT related transit centers	0.82	0.8
		Other bus stops	0.36	
	Evening peak	All bus stops near LRT stations	0.44	0.37
		LRT related transit centers	0.65	0.6
		Other bus stops	0.27	
	Night-time	All bus stops near LRT stations	0.48	0.4
		LRT related transit centers	0.69	0.62
		Other bus stops	0.27	

Note 1: BTR is bus transit reliability
Note 2: Blank cells indicate that the correlation coefficient is not significant at a 95% confidence level

From Table 12, there is a high positive correlation between bus transit reliability and ridership for bus stops near LRT stations on a typical weekday. It is potentially due to the transit user trip patterns (trips generated from/to the LRT stations). Such patterns were not observed in the Pearson correlation analysis summarized in the prior section (Table 12) where the direction of travel was not considered.

Table 12 Association between bus transit reliability by day of the week, time of the day, direction of travel, and type of bus stops

Day of the week	Time of the day	Type of bus stop	Direction of travel	BTR (-1 to 5 min)	BTR (-1 to 3 min)
Weekday	Morning peak	All bus stops near LRT stations	Inbound	0.66	0.62
			Outbound	0.52	0.45
		Bus stops near LRT stations	Inbound		
			Outbound	0.7	0.6
		Other bus stops	Inbound	0.45	0.47
			Outbound		
	Mid-day	All bus stops near LRT stations	Inbound	0.72	0.7
			Outbound	0.51	
		Bus stops near LRT stations	Inbound	0.68	
			Outbound	0.67	0.65
		Other bus stops	Inbound		
			Outbound	0.35	
	Evening peak	All bus stops near LRT stations	Inbound	0.71	0.69
			Outbound	0.46	
		Bus stops near LRT stations	Inbound	0.67	
			Outbound	0.67	0.63
		Other bus stops	Inbound	0.27	
			Outbound		
	Night-time	All bus stops near LRT stations	Inbound	0.71	0.69
			Outbound	0.51	
		Bus stops near LRT stations	Inbound	0.67	
			Outbound	0.69	
		Other bus stops	Inbound		
			Outbound		
Weekend	Morning peak	All bus stops near LRT stations	Inbound	0.52	
			Outbound		
		Other bus stops stations	Inbound		
			Outbound		
	Mid-day	All bus stops near LRT stations	Inbound	0.5	
			Outbound	0.55	0.52
		Other bus stops stations	Inbound		
			Outbound		
	Evening peak	All bus stops near LRT stations	Inbound	0.6	0.56
			Outbound		
		Other bus stops stations	Inbound		
			Outbound	0.36	
	Night-time	All bus stops near LRT stations	Inbound	0.59	0.47
			Outbound		
		Other bus stops stations	Inbound		
			Outbound		

Note 1: BTR is bus transit reliability
Note 2: Blank cells indicate that the correlation coefficient is not significant at a 95% confidence level

5.3 Discussion

The TCQSM 3rd Edition recommends OTP percentage as a measure of bus transit reliability. The deviations of the OTP percentage proposed in the manual are -1 to 5 minutes of the desired time of departure i.e., no more than 1 minute early and up to 5 minutes late (TCQSM 3rd Edition). However, this research included the computation of the deviation which lies in between 1 minutes early and 3 minutes late i.e., bus transit reliability (-1 to 3 min). This is because, the descriptive statistics of the data were calculated and identified that the median of bus transit reliability (-1 to +3 min) lies between the range 54% - 58%. This shows that the data is more normally distributed and performing the correlation results with a lesser threshold value [the value of bus transit reliability (-1 to +3 min) is less than the bus transit reliability (-1 to 5 min)] can also give significant results. From the obtained results, it can be considered that bus transit reliability (-1 to +3 min) is useful in examining the association between bus transit reliability and ridership. Based on the normality test results, it can be observed that the null hypothesis is rejected in a few cases for both bus transit reliability (-1 to +5 min) and bus transit reliability (-1 to +3 min). This may be because of the sensitivity of data to the outliers and also the presence of high variations in data (variation in bus transit reliability values and ridership values from one stop to other). Thus, it is important to examine the variations in the data and segregating by day of the week, time of the day, direction of travel, type of bus stop.

Segregating the data based on the time of the day, direction of travel, and type of bus stop yielded correlation patterns pertaining to the bus transit reliability and ridership. The Pearson correlation coefficients (absolute values) are higher when the data is examined at a granular level. A positive correlation was observed between bus transit reliability and ridership when the data was sorted by day of the week. The Pearson correlation coefficient values were almost the same for both weekday and weekend. When four different times of the day were considered, the correlation coefficient values were marginally higher from the previous scenario. A moderately higher correlation values were observed for morning peak hour and night-time hour of both weekdays and weekends. When the direction of travel was considered, a high positive correlation was observed for the inbound direction during all selected hours of the day, for both weekdays and weekends.

Due to the variation in the ridership at different bus stops, the type of bus stop is considered in the analysis. Bus stops near LRT station and transit centers near LRT station had Pearson correlation coefficients values. A high positive correlation was observed for both inbound and outbound travel directions for bus stops near LRT station due to high ridership activity. A moderate positive correlation was observed between the bus transit reliability and ridership, for other bus stops, on a typical weekday during morning peak, mid-day and evening peak hours. However, no significant correlation between bus transit reliability and ridership was observed on a weekend due to inconsistent ridership patterns for each type of bus stop.

CHAPTER 6 CONCLUSIONS

Increasing travel demand and mobility challenges call for sustainable transportation approaches such as the public transportation systems. Transportation planners and practitioners are interested in enhancing transit ridership and reliability to account for the increase in travel demand. However, recent statistics show a marginal decline in bus ridership. With emphasis on multimodal and transit-oriented developments, there is a need to understand transit reliability and its influence on ridership patterns.

This research examines the association between bus transit reliability and ridership from a transit user perspective at a bus stop level using Pearson correlation analysis. Three hundred and ninety-four geospatially distributed bus stops in the city of Charlotte, North Carolina were considered in this research. The research was conducted by categorizing the data using temporal factors (time of the day and day of the week), spatial indicator (direction of travel), and type of bus stops. The OTP percentage is considered as an indicator of bus transit reliability. The ridership is expressed in terms of the average boarding of passengers (per bus) at a bus stop level.

A total of four times of the day, two days of the week, two directions of travel, and five types of bus stops were considered for the Pearson correlation analysis. The results show that ridership has a positive association with reliability for various times of the day and days of the week. Specifically, ridership during morning peak and night-time hours of a typical weekday are highly correlated with reliability, emphasizing concentrated work trip patterns. In the case of the weekend, a moderate positive correlation between bus transit reliability and ridership was observed for all the times of the day.

The direction of travel was further used for examining the association between bus transit reliability and ridership. A high positive correlation was observed for the inbound direction during morning peak hours on a typical weekday, potentially owing to work trip patterns towards the city's central business district. Similarly, a positive correlation between bus transit reliability and ridership for the outbound direction was observed during night-time hours, potentially due to work-to-home trips.

The presence of intermodal transit services in the city influences overall transit ridership. These intermodal transit services require definite coordination in their operations for better reliability. The Pearson correlation analysis was conducted by classifying the data based on the type of bus stop to understand the influence of location parameters.

The results indicate that transit centers and bus stop near LRT stations (typically categorized as high activity bus stops) are positively correlated with the ridership. A moderate positive correlation between bus transit reliability and ridership was observed at bus stops located away from LRT stations.

The research methodology demonstrates the examination of the association between bus transit reliability and ridership at a bus stop level. The methodological approach is transferable to other regions. It can be adopted to identify the significant factors of bus transit reliability influencing ridership. The findings of this study suggest that bus transit reliability has a substantial impact on ridership.

Transit agencies should continue moving toward customer-oriented measures of reliability and satisfaction. It is possible that the values placed on reliability and ridership may not vary only based on individual characteristics but may differ on regional characteristics.

6.1 Limitations and Scope for Future Research

Bus stops within a 0.25-mile radius of each LRT station were used to analyze “bus stops related to LRT” in this research. However, bus stops that are located more than 0.25 miles away from the LRT station may also influence the bus transit ridership. Such types of bus stops are not analyzed separately. The distance and location of all bus stops can be considered as factors influencing the association between bus transit reliability and ridership.

In this research, four selected hours of the day were considered for examining the association between bus transit reliability and ridership. Other times of the day (which further increases the sample size) may be considered for better results.

The bus stops considered in this research are analyzed irrespective of the accessibility conditions present at the bus stop due to the data constraints (which means the bus stop can be easily accessible or not). Accessibility conditions may be considered to better understand the ridership and reliability patterns.

This research analyzed the relationships between bus transit reliability and the ridership data available per bus at a bus stop level. This research could further extend by considering factors like travel time, dwell time, capacity of the bus (number of passengers a bus can accommodate), number of buses that should be operated within a route, land use and socioeconomic and demographic parameters like population size and household on bus transit reliability and ridership can be examined at bus stop level.

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APPENDIX A: DESCRIPTIVE STATISTICS

This appendix summarizes the descriptive statistics by day of the week, time of the day, direction of travel and type of bus stop.

The minimum, median, mean, maximum and standard deviation values are computed for each dataset. Table A1 presents the descriptive statistics of the data based on day of the week and time of the day. A typical weekday and weekend are considered as the day of the week and four hours of the day were considered in the analysis. Tables A2 to A5 present the descriptive statistics for different types of bus stops. Table A2 presents the descriptive statistics of all the bus stops located near an LRT station within 0.25-mile buffer. Table A3 presents descriptive statistics of all the transit centers within the 0.25-mile buffer generated from each LRT station. Table A4 presents the descriptive statistics of bus stops located near an LRT station. Table A5 presents the descriptive statistics for all other stops located away from the LRT stations.

Table A1 Descriptive statistics of bus transit reliability and ridership

Time of the day	Direction of travel	Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
			Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
Morning peak	Inbound	BTR (-1 to 5 min)	5.90	2.00	80.30	85.70	75.00	77.20	99.00	97.90	94.70	21.70
		BTR (-1 to 3 min)	3.90	2.00	60.10	66.20	59.10	62.50	18.80	96.70	19.60	22.20
		Average # of boardings/bus	0.00	-	1.40	1.50	1.50	1.60	8.50	6.30	1.40	1.50
	Outbound	BTR (-1 to 5 min)	19.60	2.00	75.50	87.60	73.20	78.50	97.90	97.50	14.90	21.60
		BTR (-1 to 3 min)	15.10	2.00	55.00	68.70	53.30	64.20	89.40	94.30	15.20	20.60
		Average # of boardings/bus	0.00	-	0.40	0.50	2.90	3.80	25.60	23.30	5.40	5.60
Mid-day	Inbound	BTR (-1 to 5 min)	5.60	7.90	84.30	76.50	79.10	71.90	100.00	96.90	18.30	19.70
		BTR (-1 to 3 min)	3.80	5.80	68.10	55.60	64.50	55.00	95.90	94.90	19.50	21.00
		Average # of boardings/bus	0.00	-	1.50	1.60	1.70	1.70	272.40	6.10	1.40	1.50
	Outbound	BTR (-1 to 5 min)	15.20	15.74	80.30	78.30	75.60	74.00	97.30	96.20	15.70	16.50
		BTR (-1 to 3 min)	4.50	6.80	58.80	56.20	58.00	55.50	91.10	89.50	16.00	17.80
		Average # of boardings/bus	0.00	-	0.60	0.60	3.30	3.60	24.10	23.30	5.80	5.40
Evening peak	Inbound	BTR (-1 to 5 min)	12.80	6.00	69.10	76.60	66.40	72.00	93.30	96.50	17.20	17.60
		BTR (-1 to 3 min)	9.80	6.00	53.60	59.80	52.30	56.30	87.80	91.60	17.50	18.80
		Average # of boardings/bus	0.00	-	1.60	1.50	1.70	1.80	6.80	12.30	1.50	2.10
	Outbound	BTR (-1 to 5 min)	23.30	28.10	60.00	76.90	58.40	73.40	90.00	97.20	14.60	13.70
		BTR (-1 to 3 min)	3.20	7.80	41.80	56.50	41.60	54.10	78.10	88.90	13.00	15.90
		Average # of boardings/bus	0.00	-	0.50	0.60	3.50	4.10	30.90	33.47	6.70	6.90
Night-time	Inbound	BTR (-1 to 5 min)	3.20	20.20	83.50	78.00	77.70	73.50	97.10	99.50	18.90	18.90
		BTR (-1 to 3 min)	1.60	19.20	64.10	57.00	62.30	57.50	94.60	95.50	18.60	20.80
		Average # of boardings/bus	0.00	-	1.50	1.60	1.50	1.60	7.10	9.70	1.40	1.80
	Outbound	BTR (-1 to 5 min)	24.80	29.90	81.10	77.90	77.00	74.40	97.80	96.20	14.70	14.40
		BTR (-1 to 3 min)	10.40	7.70	57.90	56.20	57.60	55.10	90.40	88.40	15.70	17.70
		Average # of boardings/bus	0.00	-	0.40	0.50	3.60	3.90	23.30	27.40	5.90	6.10

Note: BTR is bus transit reliability

Table A2 Descriptive statistics of all bus stops near an LRT station

		Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
			Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
All records greater than 30		BTR (-1 to 5 min)	9.85	13.10	77.26	77.80	70.57	71.90	93.19	95.30	18.06	17.60
		BTR (-1 to 3 min)	7.80	11.60	55.59	40.50	54.42	56.70	83.75	80.40	15.90	16.10
		Average # of boardings/bus	0.00	0.00	1.29	1.00	4.76	4.20	22.32	25.90	6.25	5.70
Morning peak		BTR (-1 to 5 min)	5.94	2.00	69.98	86.00	69.54	77.84	97.26	97.93	19.90	21.60
		BTR (-1 to 3 min)	3.88	2.00	50.18	66.45	51.65	63.26	91.78	96.70	18.96	21.45
		Average # of boardings/bus	0.00	0.00	1.35	1.00	4.99	2.59	25.64	23.33	6.56	4.14
Mid-day		BTR (-1 to 5 min)	9.85	7.90	74.54	67.30	69.93	66.40	93.19	93.80	18.32	21.30
		BTR (-1 to 3 min)	7.80	5.80	53.43	50.70	53.94	50.40	83.75	86.00	16.09	20.70
		Average # of boardings/bus	0.00	0.00	1.95	1.40	5.03	4.50	22.32	23.30	6.40	5.70
Evening peak		BTR (-1 to 5 min)	9.85	6.00	75.11	76.00	70.46	71.00	93.19	97.20	18.11	18.60
		BTR (-1 to 3 min)	7.80	6.00	54.10	57.00	54.31	54.70	83.75	91.60	16.07	18.20
		Average # of boardings/bus	0.00	0.00	1.69	1.30	4.94	5.30	22.32	33.40	6.35	7.40
Night-time		BTR (-1 to 5 min)	20.19	20.20	74.19	74.20	72.12	72.10	97.00	97.00	18.25	18.20
		BTR (-1 to 3 min)	19.23	19.20	56.81	56.80	55.96	56.00	85.57	85.60	18.29	18.30
		Average # of boardings/bus	0.00	0.00	1.00	0.90	4.65	4.50	28.40	27.40	8.40	6.40
Morning peak	Inbound	BTR (-1 to 5 min)	5.90	2.00	58.50	61.20	60.10	60.10	97.30	96.90	21.80	24.70
		BTR (-1 to 3 min)	3.90	2.00	43.10	48.90	45.80	48.00	91.80	87.60	20.30	22.70
		Average # of boardings/bus	0.00	0.00	0.00	0.00	0.70	0.50	4.70	137.20	1.20	1.00
	Outbound	BTR (-1 to 5 min)	55.94	26.00	81.76	89.20	78.98	86.00	96.92	97.50	12.02	94.30
		BTR (-1 to 3 min)	15.54	22.90	57.08	72.20	57.53	71.10	88.72	13.10	15.60	14.50
		Average # of boardings/bus	0.00	0.00	9.76	8.10	9.28	8.30	25.64	23.30	6.94	6.10
Mid-day	Inbound	BTR (-1 to 5 min)	9.85	7.90	56.53	56.10	60.54	56.40	93.19	88.70	19.36	18.80
		BTR (-1 to 3 min)	7.80	5.80	43.57	41.40	47.89	42.70	83.75	77.50	17.32	
		Average # of boardings/bus	0.00	0.00	0.03	0.00	0.78	0.60	4.68	6.10	1.33	1.30
	Outbound	BTR (-1 to 5 min)	38.59	49.20	82.39	85.00	79.32	81.60	93.13	96.20	11.12	11.30
		BTR (-1 to 3 min)	30.12	22.70	60.43	65.00	60.00	62.90	81.33	88.00	12.21	16.50
		Average # of boardings/bus	0.00	0.00	11.08	8.30	9.28	8.10	22.32	23.30	6.63	6.00
Evening peak	Inbound	BTR (-1 to 5 min)	36.80	6.00	70.40	61.31	77.20	61.50	98.20	96.50	32.30	21.09
		BTR (-1 to 3 min)	26.40	6.00	56.30	46.90	55.20	48.36	94.40	91.61	21.20	18.86
		Average # of boardings/bus	0.00	0.00	0.01	0.01	0.70	0.70	4.30	4.30	1.39	1.39
	Outbound	BTR (-1 to 5 min)	57.43	57.43	81.28	81.28	79.96	79.96	97.22	97.22	9.60	9.60
		BTR (-1 to 3 min)	24.37	24.37	60.00	60.00	60.67	60.67	88.89	88.89	15.51	15.51
		Average # of boardings/bus	0.00	0.00	7.82	7.82	9.73	9.73	33.39	33.39	8.14	8.14
Night-time	Inbound	BTR (-1 to 5 min)	9.85	20.20	56.37	59.40	59.99	63.20	93.19	97.00	19.28	19.90
		BTR (-1 to 3 min)	7.80	19.20	43.26	30.10	47.39	44.20	83.75	85.30	17.18	18.50
		Average # of boardings/bus	0.00	0.00	0.03	0.00	0.75	0.60	4.68	3.50	1.33	1.20
	Outbound	BTR (-1 to 5 min)	56.05	56.00	82.39	85.50	80.03	81.00	93.13	96.20	9.11	10.80
		BTR (-1 to 3 min)	30.12	26.50	60.43	67.50	60.22	32.70	81.33	85.60	11.24	15.70
		Average # of boardings/bus	0.00	0.00	11.33	8.40	9.59	8.70	22.32	27.40	6.62	6.90

Note: BTR is bus transit reliability

Table A3 Descriptive statistics of transit centers near an LRT station

		Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
			Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
All records greater than 30		BTR (-1 to 5 min)	9.85	13.10	66.08	68.80	65.95	68.40	90.32	89.70	19.72	17.50
		BTR (-1 to 3 min)	7.80	11.60	50.00	52.60	49.49	53.10	74.53	78.80	15.32	15.30
		Average # of boardings/bus	0.00	0.00	2.84	2.80	6.79	6.00	22.32	7531.30	7.45	6.70
Morning peak		BTR (-1 to 5 min)	5.94	19.10	66.90	80.20	64.24	70.40	91.92	96.90	21.47	23.10
		BTR (-1 to 3 min)	3.88	5.60	46.69	59.80	46.80	56.40	79.09	88.10	17.32	21.30
		Average # of boardings/bus	0.00	0.00	2.45	2.60	6.25	5.70	21.83	23.30	7.16	6.60
Mid-day		BTR (-1 to 5 min)	9.85	7.90	66.08	67.30	65.95	66.40	90.32	93.80	19.72	86.00
		BTR (-1 to 3 min)	7.80	5.80	50.00	50.70	49.49	50.40	74.53	21.30	15.32	20.70
		Average # of boardings/bus	0.00	0.00	2.84	2.40	6.79	5.80	22.32	23.30	7.45	6.60
Evening peak		BTR (-1 to 5 min)	9.85	6.00	66.08	73.30	65.95	67.10	90.32	92.70	19.72	18.80
		BTR (-1 to 3 min)	7.80	6.00	50.00	52.10	49.49	50.90	74.53	81.80	15.32	17.00
		Average # of boardings/bus	0.00	0.00	2.84	3.00	6.79	7.10	22.32	33.40	7.45	8.60
Night-time		BTR (-1 to 5 min)	33.70	33.70	72.37	72.40	69.80	69.80	92.78	92.80	17.79	17.80
		BTR (-1 to 3 min)	26.95	27.00	52.22	52.20	53.97	54.00	85.57	85.60	16.98	17.00
		Average # of boardings/bus	0.00	0.00	0.19	0.20	6.26	6.30	27.39	27.40	7.45	7.50
Morning peak	Inbound	BTR (-1 to 5 min)	5.94	19.10	50.44	51.00	46.57	52.10	72.30	80.60	15.07	18.50
		BTR (-1 to 3 min)	3.88	5.60	35.34	41.00	33.88	42.30	60.47	66.70	12.13	17.80
		Average # of boardings/bus	0.00	0.00	0.00	0.00	0.02	0.00	0.16	0.60	0.04	0.10
	Outbound	BTR (-1 to 5 min)	66.40	26.00	84.49	89.20	81.91	86.00	91.92	97.50	7.99	13.10
		BTR (-1 to 3 min)	39.13	22.90	62.87	72.00	59.72	71.10	79.09	94.30	10.86	14.50
		Average # of boardings/bus	4.74	4.50	12.49	10.20	12.49	11.30	21.83	23.30	4.87	4.60
Mid-day	Inbound	BTR (-1 to 5 min)	9.85	7.90	53.95	49.60	49.19	48.30	67.78	71.40	13.27	12.80
		BTR (-1 to 3 min)	7.80	5.80	41.30	36.00	37.67	34.90	53.23	63.70	10.42	14.00
		Average # of boardings/bus	0.00	0.00	0.03	0.00	0.03	0.10	0.10	0.90	0.03	0.20
	Outbound	BTR (-1 to 5 min)	63.68	57.30	83.70	87.80	82.71	84.50	90.32	93.80	5.72	9.10
		BTR (-1 to 3 min)	42.70	30.20	60.47	66.40	61.30	65.80	74.53	86.00	8.94	13.50
		Average # of boardings/bus	5.57	3.90	12.76	11.40	13.55	11.40	22.32	23.30	4.26	4.60
Evening peak	Inbound	BTR (-1 to 5 min)	9.85	6.00	53.95	57.78	49.19	53.46	67.78	77.89	13.27	16.76
		BTR (-1 to 3 min)	7.80	6.00	41.30	42.43	37.67	40.90	53.23	65.12	10.42	15.13
		Average # of boardings/bus	0.00	0.00	0.03	0.00	0.03	0.02	0.10	0.21	0.03	0.05
	Outbound	BTR (-1 to 5 min)	63.68	6.00	83.70	73.32	82.71	67.13	90.32	92.67	5.72	18.77
		BTR (-1 to 3 min)	42.70	6.00	60.47	52.13	61.30	50.93	74.53	81.82	8.94	17.00
		Average # of boardings/bus	5.57	0.00	12.76	2.98	13.55	7.07	22.32	33.39	4.26	8.59
Night-time	Inbound	BTR (-1 to 5 min)	9.85	33.70	53.95	56.30	49.19	56.90	67.78	84.10	13.27	14.80
		BTR (-1 to 3 min)	7.80	27.00	41.30	41.60	37.67	43.50	53.23	73.30	10.42	13.50
		Average # of boardings/bus	0.00	0.00	0.03	0.00	0.03	0.00	0.10	0.20	0.03	0.10
	Outbound	BTR (-1 to 5 min)	63.68	68.80	83.70	85.90	82.71	83.30	90.32	92.80	5.72	7.70
		BTR (-1 to 3 min)	42.70	39.50	60.47	67.80	61.30	65.00	74.53	85.60	8.94	12.80
		Average # of boardings/bus	5.57	5.50	12.76	12.50	13.55	12.80	22.32	27.40	4.26	5.40

Note: BTR is bus transit reliability

Table A4 Descriptive statistics of bus stops near an LRT station

		Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
			Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
All Records greater than 30		BTR (-1 to 5 min)	38.59	14.66	80.29	80.44	76.21	76.77	93.19	95.29	14.08	16.77
		BTR (-1 to 3 min)	30.12	13.10	59.63	67.61	60.43	61.76	83.75	80.37	14.62	16.07
		Average # of boardings/bus	0.00	0.00	1.29	1.04	2.27	1.74	12.78	9.84	2.88	2.12
Morning peak		BTR (-1 to 5 min)	44.98	2.04	79.58	87.29	76.91	77.91	97.26	97.54	14.83	24.18
		BTR (-1 to 3 min)	15.54	2.04	58.87	70.50	58.38	65.40	91.78	94.26	19.30	22.91
		Average # of boardings/bus	0.00	0.00	1.35	1.12	3.24	1.95	25.64	13.84	5.24	3.03
Mid-day		BTR (-1 to 5 min)	38.59	21.21	77.32	77.58	75.78	74.80	93.19	96.24	14.40	15.75
		BTR (-1 to 3 min)	30.12	20.20	59.32	61.25	60.50	58.19	83.75	87.97	15.11	18.19
		Average # of boardings/bus	0.00	0.00	1.95	1.37	2.44	2.07	12.78	10.66	2.99	2.49
Evening peak		BTR (-1 to 5 min)	45.44	24.27	80.51	82.35	76.72	78.08	93.19	97.22	13.52	16.37
		BTR (-1 to 3 min)	30.12	24.27	59.35	65.38	61.01	61.60	83.75	91.61	14.79	18.59
		Average # of boardings/bus	0.00	0.00	1.69	1.25	2.36	2.13	12.78	9.80	2.93	2.40
Night-time		BTR (-1 to 5 min)	45.44	20.19	75.65	83.17	76.23	76.11	93.19	97.00	13.12	18.70
		BTR (-1 to 3 min)	30.12	19.23	59.01	62.07	60.57	59.40	83.75	85.31	14.40	20.25
		Average # of boardings/bus	0.00	0.00	1.72	0.89	2.41	1.88	12.78	8.31	3.01	2.09
Morning peak	Inbound	BTR (-1 to 5 min)	44.98	2.04	80.82	87.76	78.91	74.78	97.26	96.88	14.41	28.39
		BTR (-1 to 3 min)	27.55	2.04	62.01	68.75	62.27	60.49	91.78	87.63	17.80	25.97
		Average # of boardings/bus	0.00	0.00	1.65	1.18	1.67	1.34	4.69	4.26	1.42	1.36
	Outbound	BTR (-1 to 5 min)	55.94	26.04	74.61	86.83	74.91	81.03	96.92	97.54	15.38	19.78
		BTR (-1 to 3 min)	15.54	22.92	56.02	72.16	54.48	70.31	88.72	94.26	20.44	19.15
		Average # of boardings/bus	0.00	0.00	1.28	1.06	4.81	2.57	25.64	13.84	7.01	4.05
Mid-day	Inbound	BTR (-1 to 5 min)	45.44	21.21	85.16	78.01	77.22	72.70	93.19	88.73	14.13	18.62
		BTR (-1 to 3 min)	38.24	20.20	59.63	61.25	62.91	58.39	83.75	77.49	14.25	16.28
		Average # of boardings/bus	0.00	0.00	2.41	1.49	1.87	1.67	4.68	6.08	1.55	1.83
	Outbound	BTR (-1 to 5 min)	38.59	49.22	74.56	76.00	74.33	76.60	93.13	96.24	14.94	13.26
		BTR (-1 to 3 min)	30.12	22.66	56.21	59.57	58.09	58.01	81.33	87.97	15.98	20.30
		Average # of boardings/bus	0.00	0.00	1.66	1.37	3.02	2.41	12.78	10.66	3.92	2.96
Evening peak	Inbound	BTR (-1 to 5 min)	45.44	24.27	85.16	85.19	76.47	77.57	93.19	96.50	15.14	20.13
		BTR (-1 to 3 min)	34.52	24.27	59.63	65.38	62.18	63.28	83.75	91.61	15.38	17.01
		Average # of boardings/bus	0.00	0.00	2.18	2.65	1.75	2.05	4.68	4.30	1.52	1.77
	Outbound	BTR (-1 to 5 min)	56.05	57.43	78.99	79.64	76.99	78.51	93.13	97.22	11.90	13.12
		BTR (-1 to 3 min)	30.12	24.37	59.07	65.86	59.70	60.17	81.33	88.89	14.46	20.37
		Average # of boardings/bus	0.00	0.00	1.66	0.99	3.04	2.20	12.78	9.80	3.90	2.90
Night-time	Inbound	BTR (-1 to 5 min)	45.44	20.19	80.70	82.88	76.85	74.78	93.19	97.00	14.56	23.37
		BTR (-1 to 3 min)	38.24	19.23	59.32	58.70	62.58	59.80	83.75	85.31	14.50	21.99
		Average # of boardings/bus	0.00	0.00	2.41	2.04	1.88	1.64	4.68	3.55	1.59	1.46
	Outbound	BTR (-1 to 5 min)	56.05	56.03	74.56	83.17	75.56	77.34	93.13	96.15	11.88	13.98
		BTR (-1 to 3 min)	30.12	26.49	56.21	63.83	58.43	59.03	81.33	83.33	14.48	19.40
		Average # of boardings/bus	0.00	0.00	1.66	0.84	2.98	2.11	12.78	8.31	4.01	2.57

Note: BTR is bus transit reliability

Table A5 Descriptive statistics of other bus stops

		Variable	Minimum		Median		Mean		Maximum		Std. Dev.	
			Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
All Records greater than 30		BTR (-1 to 5 min)	14.69	18.25	78.81	81.98	75.95	78.15	100.00	96.97	13.78	14.06
		BTR (-1 to 3 min)	1.57	15.14	60.48	63.00	59.51	60.88	90.38	90.91	14.85	16.16
		Average # of boardings/bus	0.00	0.00	0.94	0.90	1.24	1.19	9.34	7.39	1.33	1.22
Morning peak		BTR (-1 to 5 min)	5.94	2.00	77.44	88.30	73.77	80.86	98.99	97.93	17.20	19.89
		BTR (-1 to 3 min)	3.88	2.00	56.57	71.58	55.91	65.50	94.67	96.70	17.52	20.80
		Average # of boardings/bus	0.00	0.00	0.66	0.97	2.08	1.38	21.83	6.28	3.82	1.48
Mid-day		BTR (-1 to 5 min)	27.69	15.69	82.91	78.58	79.50	75.07	100.00	96.94	14.54	16.88
		BTR (-1 to 3 min)	4.53	6.84	64.83	56.22	63.20	56.42	95.92	94.90	16.94	19.21
		Average # of boardings/bus	0.00	0.00	1.07	1.27	1.28	1.43	5.96	5.35	1.22	1.37
Evening peak		BTR (-1 to 5 min)	12.83	28.13	62.40	76.61	62.09	73.68	93.33	92.78	16.22	13.58
		BTR (-1 to 3 min)	3.19	7.77	45.14	57.17	46.77	55.26	87.78	89.69	16.10	17.10
		Average # of boardings/bus	0.00	0.00	0.92	0.85	2.62	1.34	30.88	9.61	5.17	1.64
Night-time		BTR (-1 to 5 min)	24.83	29.86	82.91	78.52	79.59	74.90	97.14	99.50	13.99	15.89
		BTR (-1 to 3 min)	10.36	7.69	63.20	56.20	61.63	56.28	94.63	95.54	16.43	20.25
		Average # of boardings/bus	0.00	0.00	1.15	1.07	1.24	1.37	7.07	9.68	1.28	1.60
Morning peak	Inbound	BTR (-1 to 5 min)	26.67	31.13	84.74	90.97	80.94	87.94	98.99	97.93	13.81	10.27
		BTR (-1 to 3 min)	15.56	18.28	65.48	76.00	64.42	71.64	94.67	96.70	16.70	16.98
		Average # of boardings/bus	0.00	0.00	1.61	1.96	1.78	2.22	8.47	6.28	1.33	1.41
	Outbound	BTR (-1 to 5 min)	19.61	2.00	73.66	80.71	70.80	71.77	97.87	96.00	15.61	25.07
		BTR (-1 to 3 min)	15.06	2.00	53.09	57.18	51.34	57.63	89.36	91.03	14.94	22.71
		Average # of boardings/bus	0.00	0.00	0.13	0.02	0.47	0.31	7.25	3.99	1.00	0.64
Mid-day	Inbound	BTR (-1 to 5 min)	51.01	35.71	88.38	85.09	86.09	81.01	100.00	96.94	9.65	13.60
		BTR (-1 to 3 min)	25.34	15.31	73.02	65.90	70.70	62.12	95.92	94.90	14.44	19.24
		Average # of boardings/bus	0.00	0.00	1.69	2.00	1.95	2.24	5.96	5.35	1.23	1.24
	Outbound	BTR (-1 to 5 min)	27.69	15.69	75.51	70.85	72.66	68.20	97.26	93.01	15.60	17.79
		BTR (-1 to 3 min)	4.53	6.84	56.58	51.24	55.41	49.83	91.10	89.51	15.83	17.09
		Average # of boardings/bus	0.00	0.00	0.35	0.24	0.59	0.50	4.06	4.46	0.73	0.80
Evening peak	Inbound	BTR (-1 to 5 min)	35.38	54.95	72.59	80.69	71.45	78.92	93.33	92.78	13.30	10.16
		BTR (-1 to 3 min)	21.35	20.00	58.37	64.03	56.71	61.43	87.78	89.69	15.63	17.19
		Average # of boardings/bus	0.00	0.00	1.75	2.03	1.96	2.34	6.50	9.61	1.31	1.79
	Outbound	BTR (-1 to 5 min)	23.29	28.13	56.23	71.57	53.92	68.81	80.67	88.81	13.61	14.59
		BTR (-1 to 3 min)	3.19	7.77	39.71	52.01	38.84	49.53	64.51	80.41	12.22	15.01
		Average # of boardings/bus	0.00	0.00	0.22	0.15	0.46	0.41	2.95	3.29	0.61	0.65
Night-time	Inbound	BTR (-1 to 5 min)	66.00	37.89	86.81	85.14	86.44	80.30	97.14	99.50	7.05	14.97
		BTR (-1 to 3 min)	30.85	20.95	71.50	63.57	69.71	63.09	94.63	95.54	12.68	20.73
		Average # of boardings/bus	0.00	0.12	1.83	1.89	2.02	2.29	7.07	9.68	1.26	1.71
	Outbound	BTR (-1 to 5 min)	24.83	29.86	75.26	68.63	72.08	69.01	96.60	95.21	15.81	14.86
		BTR (-1 to 3 min)	10.36	7.69	54.40	49.66	52.77	48.87	86.39	88.36	15.56	17.03
		Average # of boardings/bus	0.00	0.00	0.13	0.16	0.38	0.37	2.46	2.33	0.56	0.53

Note: BTR is bus transit reliability

APPENDIX B: HISTOGRAMS

This appendix summarizes the histograms generated for examining distributions by day of the week, time of the day, direction of travel, and type of bus stop. Figures B1 to B13 represents the histograms of bus transit reliability (-1 to +5 min) and bus transit reliability (-1 to +3 min) by weekday, weekend and also for considered hours of the day along with the direction of travel.

Figure B1 presents the distribution of bus transit reliability on a weekday and weekend. Figure B2 presents the distribution of bus transit reliability on a morning peak hour of weekdays and weekend. Figure B3 presents the distribution of bus transit reliability during mid-day hour of weekdays and weekend. Figures B4 and B5 presents the distribution of bus transit reliability during evening peak hour and night-time of weekdays and weekend.

Figures B6 to B13 presents the distribution of bus transit reliability by the direction of travel (inbound and outbound direction) for morning peak, mid-day, evening peak, and night-time hours. Figures B6 and B7 presents the distribution of bus transit reliability by the direction of travel on weekdays and weekend during morning peak hour. Figures B8 and B9 presents the distribution of bus transit reliability by the direction of travel on weekdays and weekend during mid-day hour. Figures B10 and B11 presents the distribution of bus transit reliability by the direction of travel on weekdays and weekend during evening peak hour. Figures B12 and B13 presents the distribution of bus transit reliability by the direction of travel on weekdays and weekend during night-time hour.

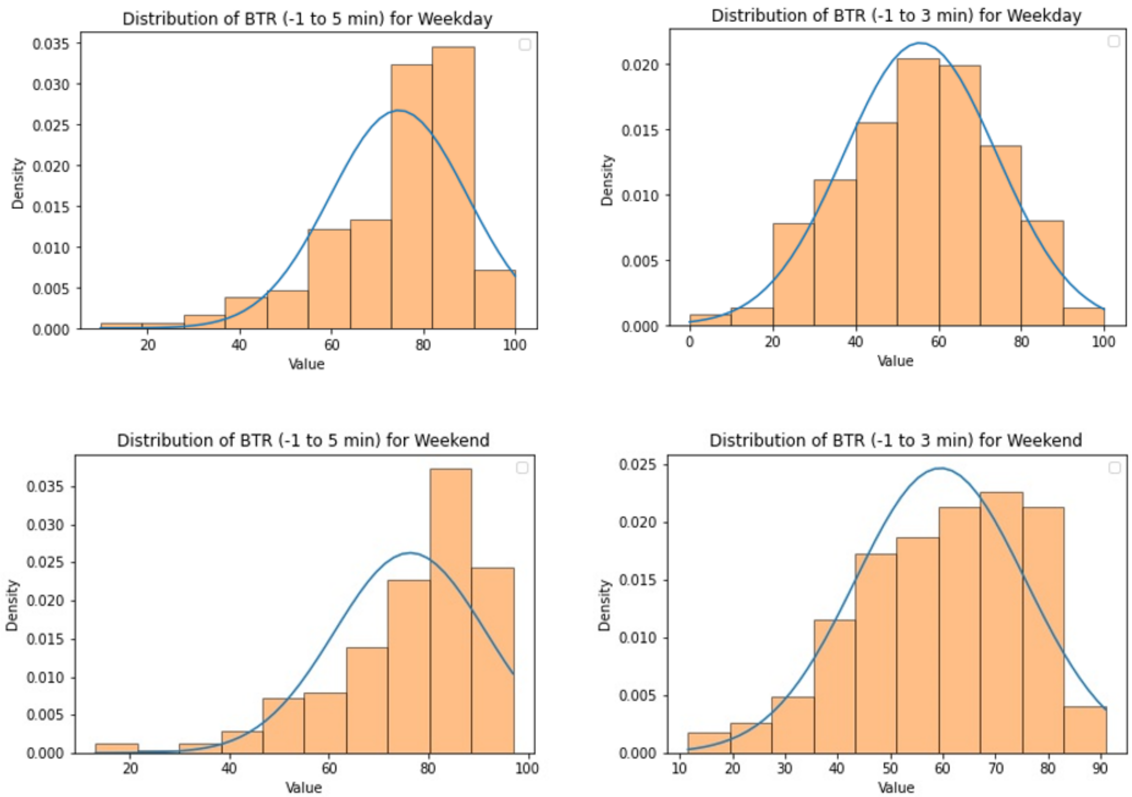

Figure B1 Distribution of bus transit reliability on a weekday and weekend

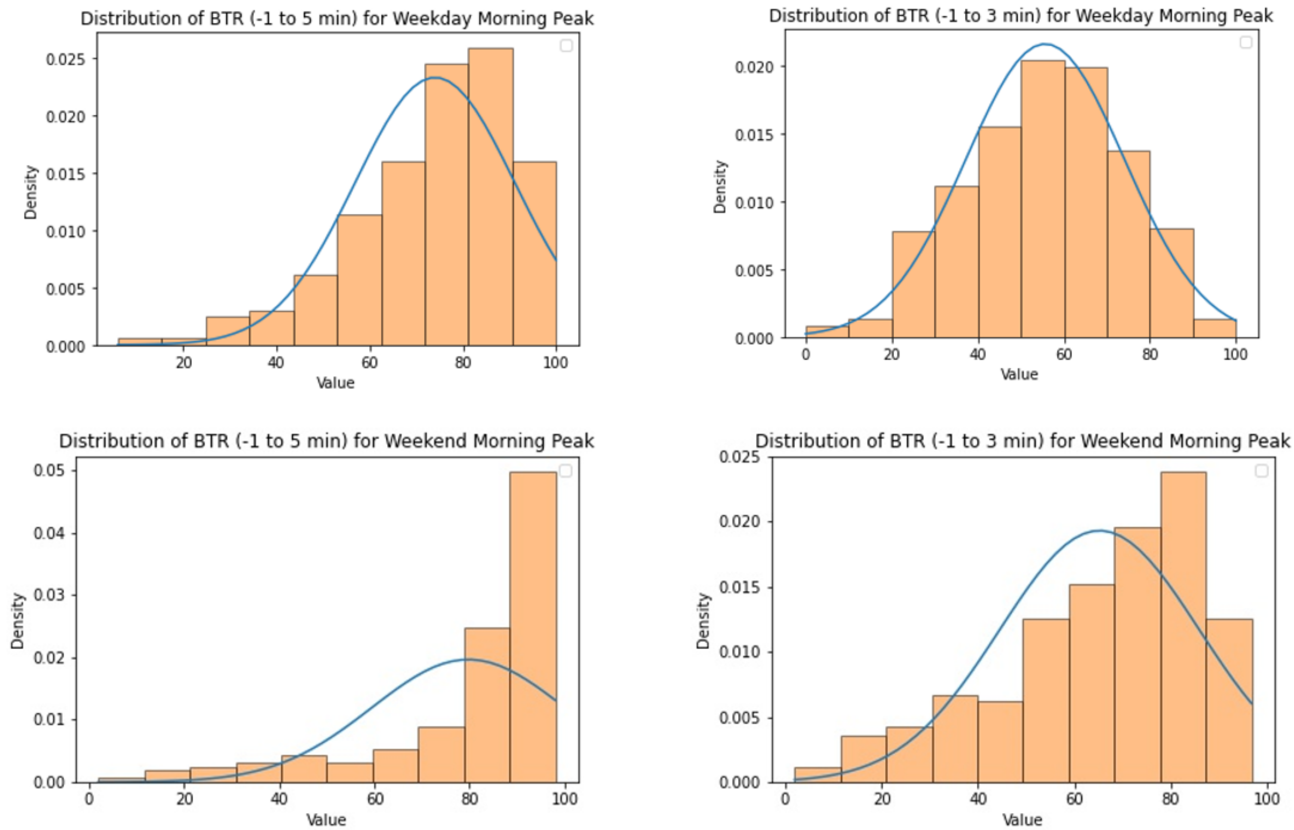

Figure B2 Distribution of bus transit reliability during morning peak hour on a weekday and weekend

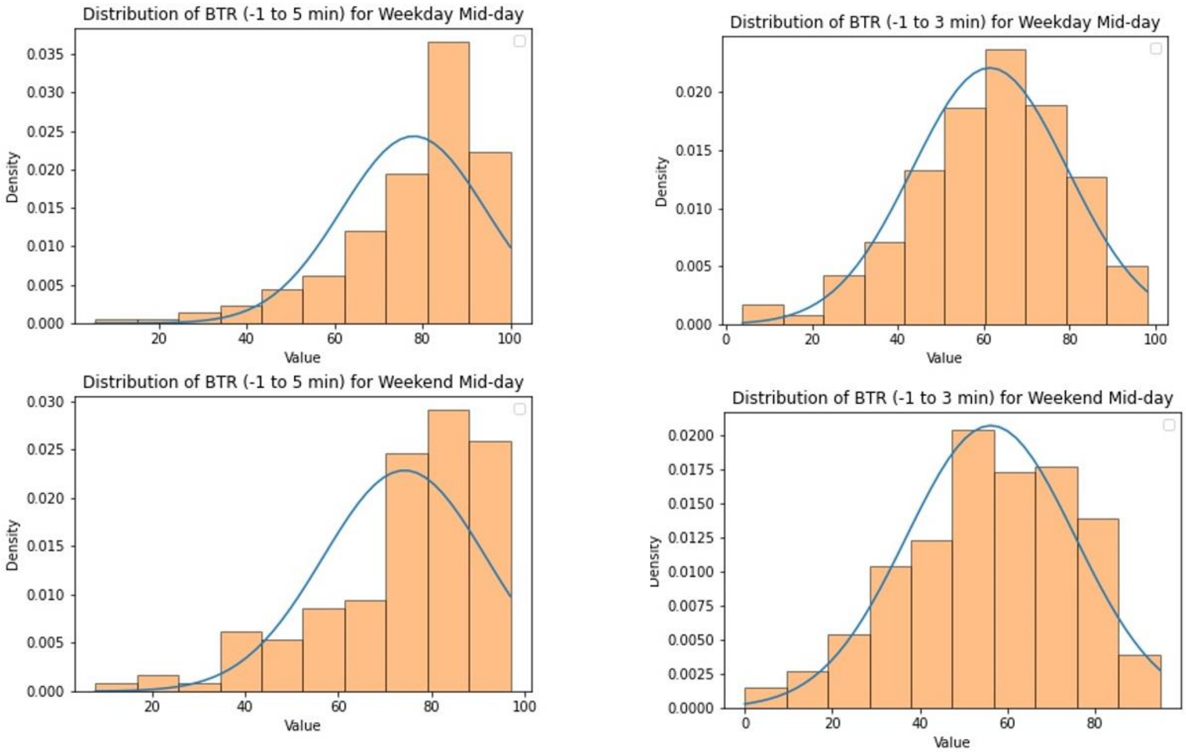

Figure B3 Distribution of bus transit reliability during mid-day hour on a weekday and weekend

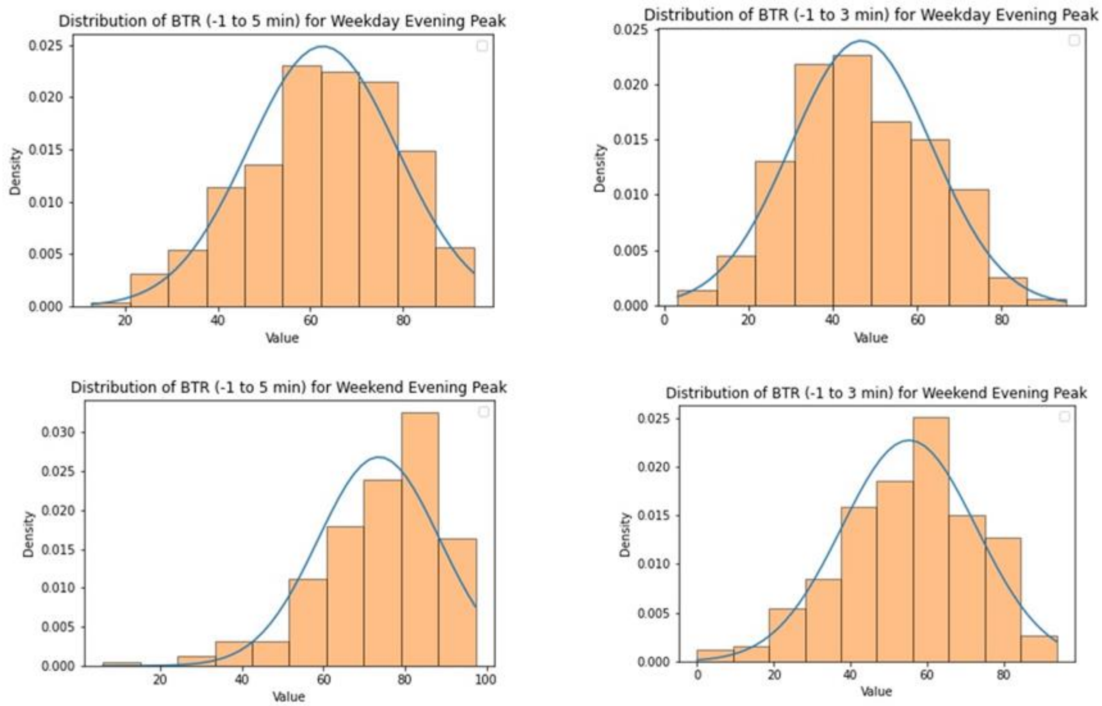

Figure B4 Distribution of bus transit reliability during evening peak hour on a weekday and weekend

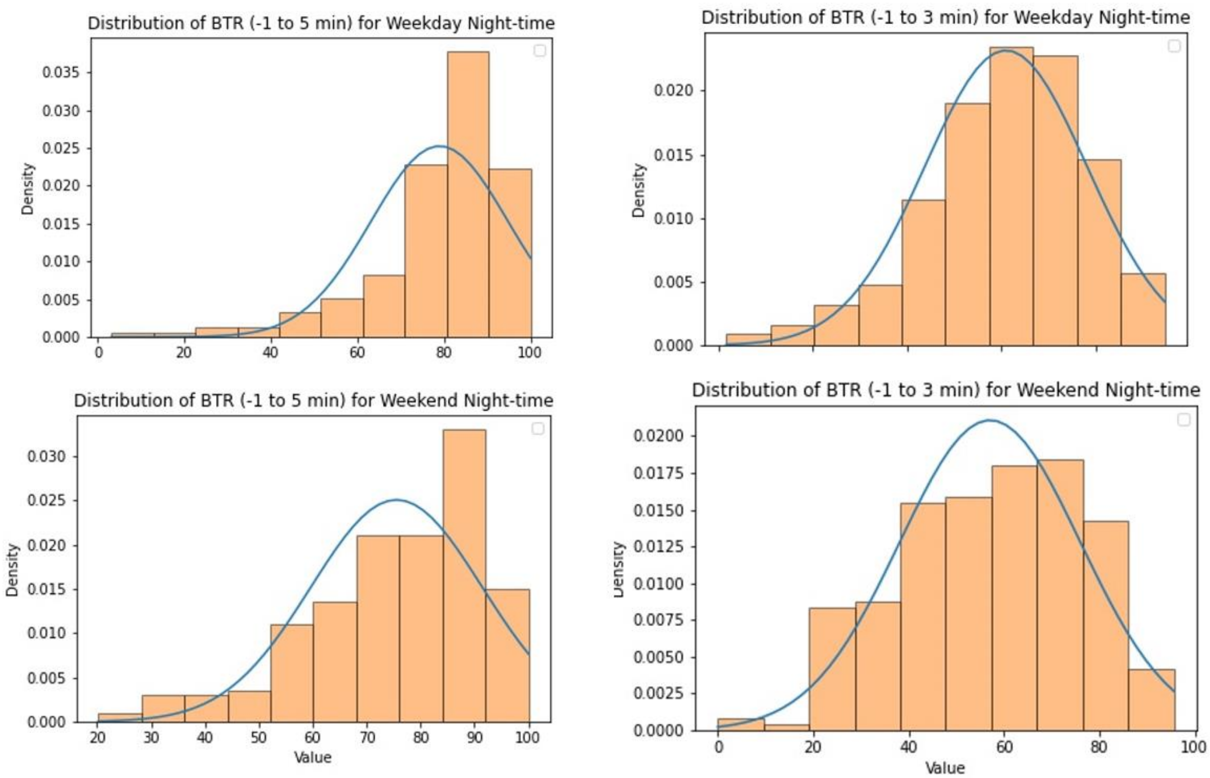

Figure B3 Distribution of bus transit reliability during night-time hour on a weekday and weekend

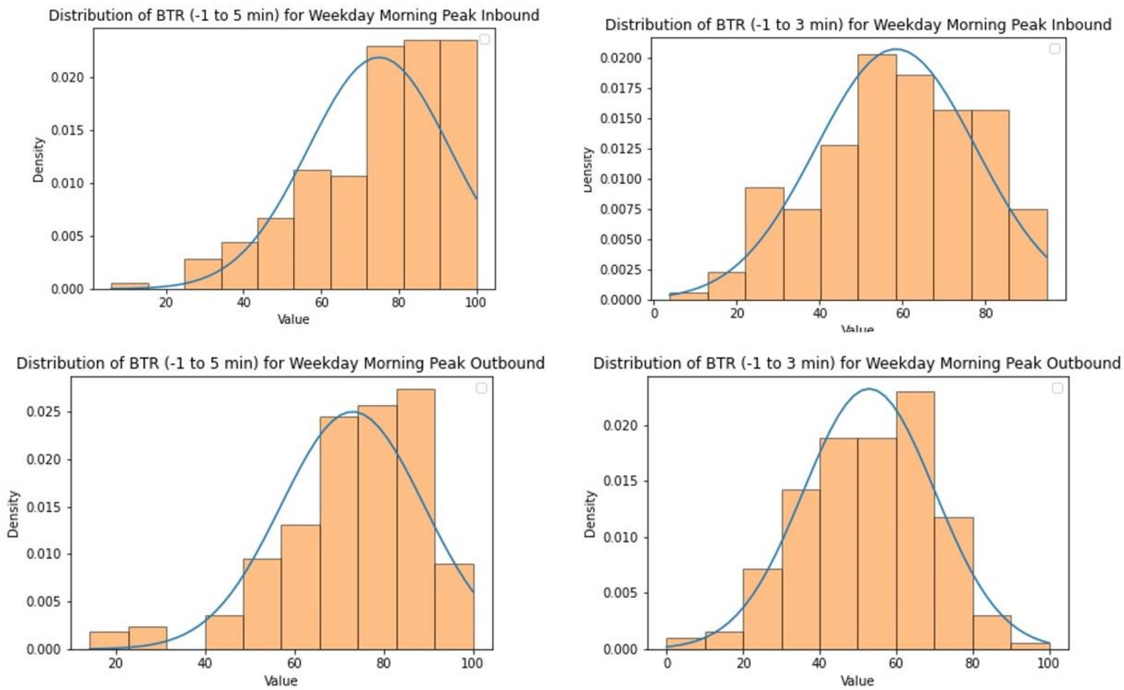

Figure B4 Distribution of bus transit reliability during morning peak hour on a weekday (inbound and outbound direction)

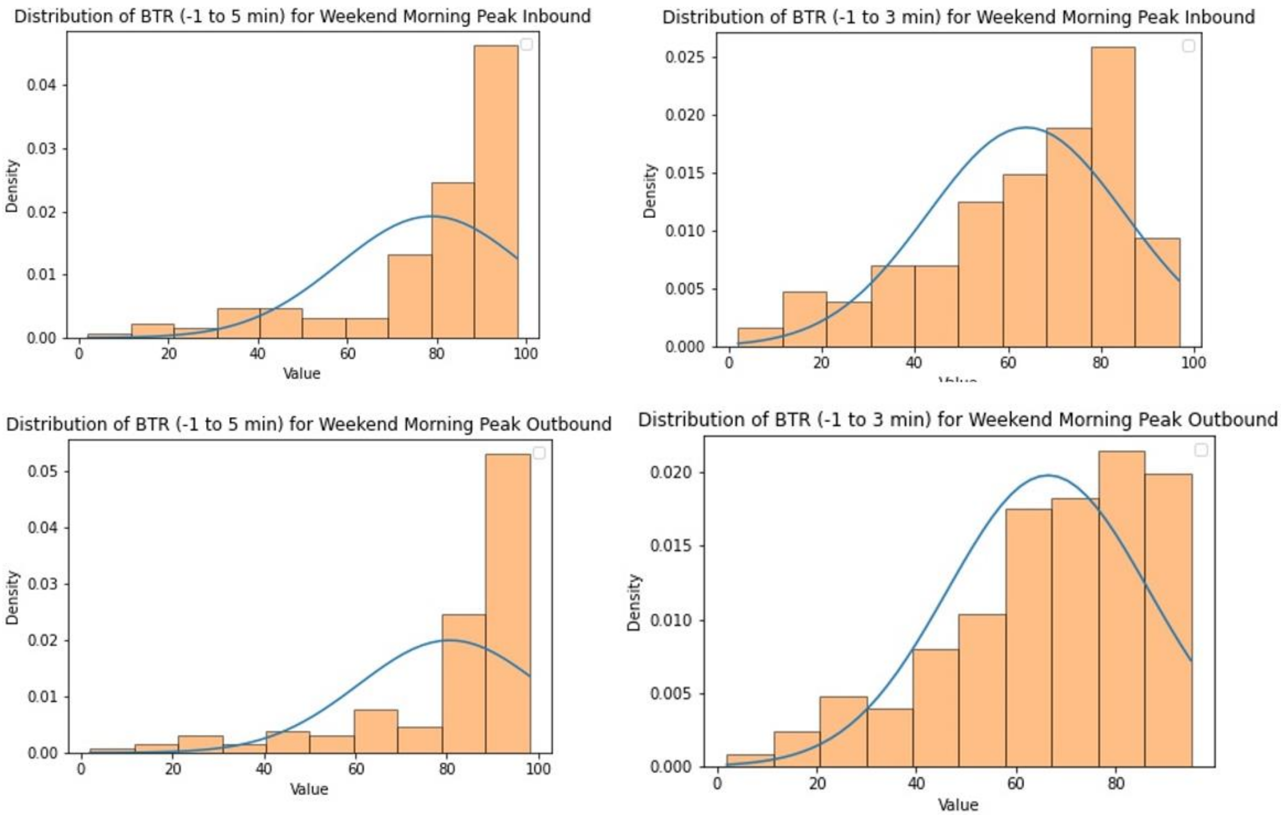

Figure B5 Distribution of bus transit reliability during morning peak hour on a weekend (inbound and outbound direction)

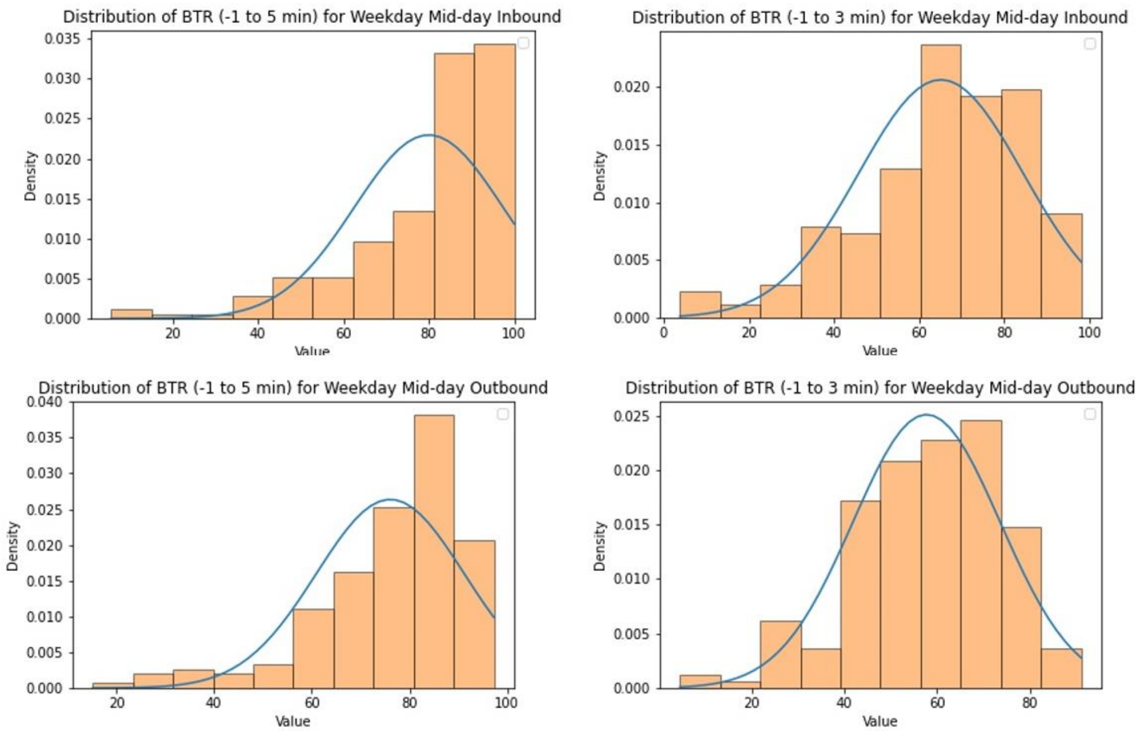

Figure B6 Distribution of bus transit reliability during mid-day hour on a weekday (inbound and outbound direction)

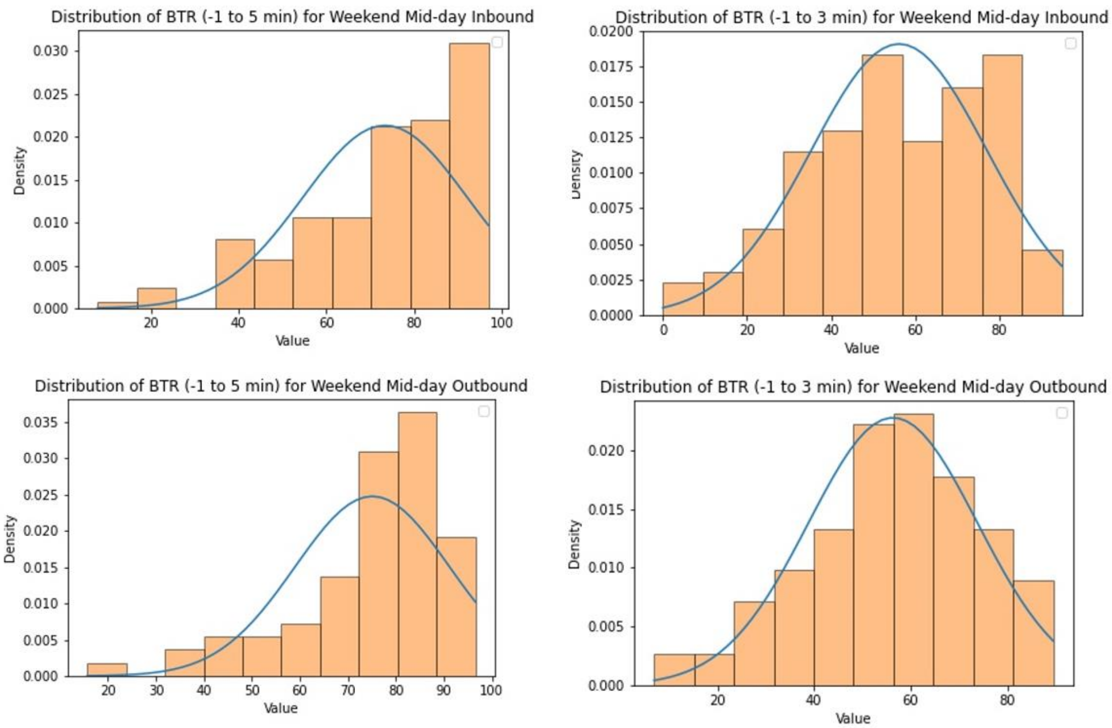

Figure B7 Distribution of bus transit reliability during mid-day hour on a weekend (inbound and outbound direction)

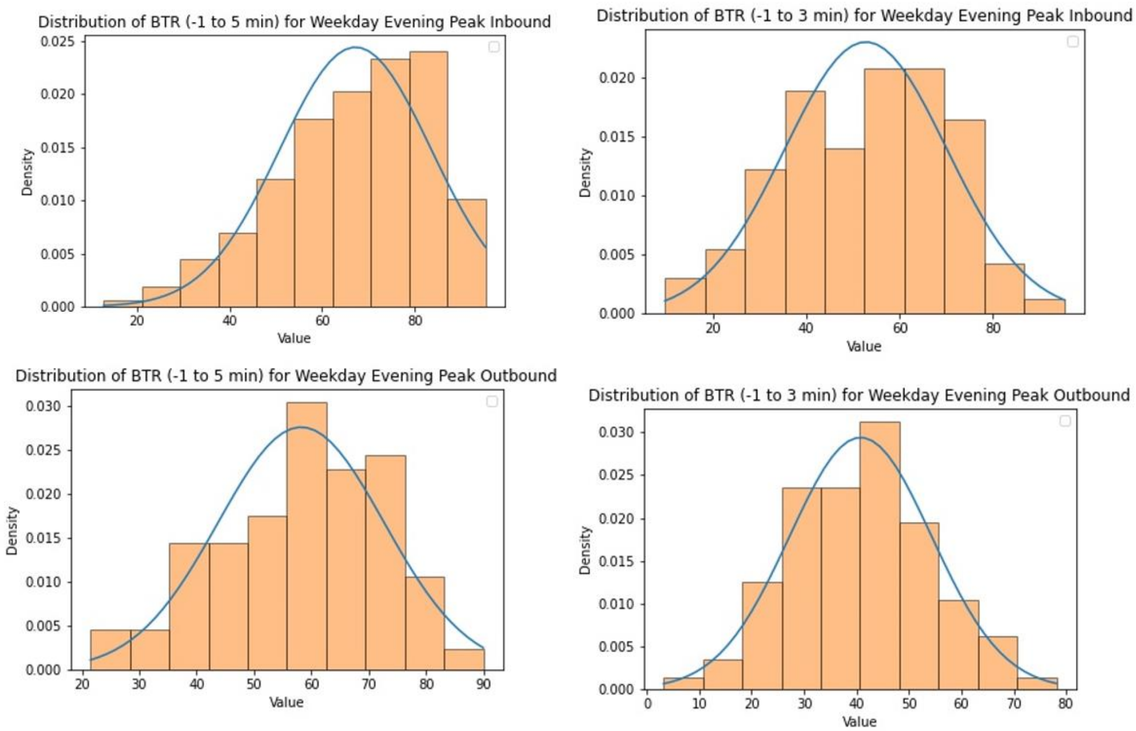

Figure B8 Distribution of bus transit reliability during evening peak hour on a weekday (inbound and outbound direction)

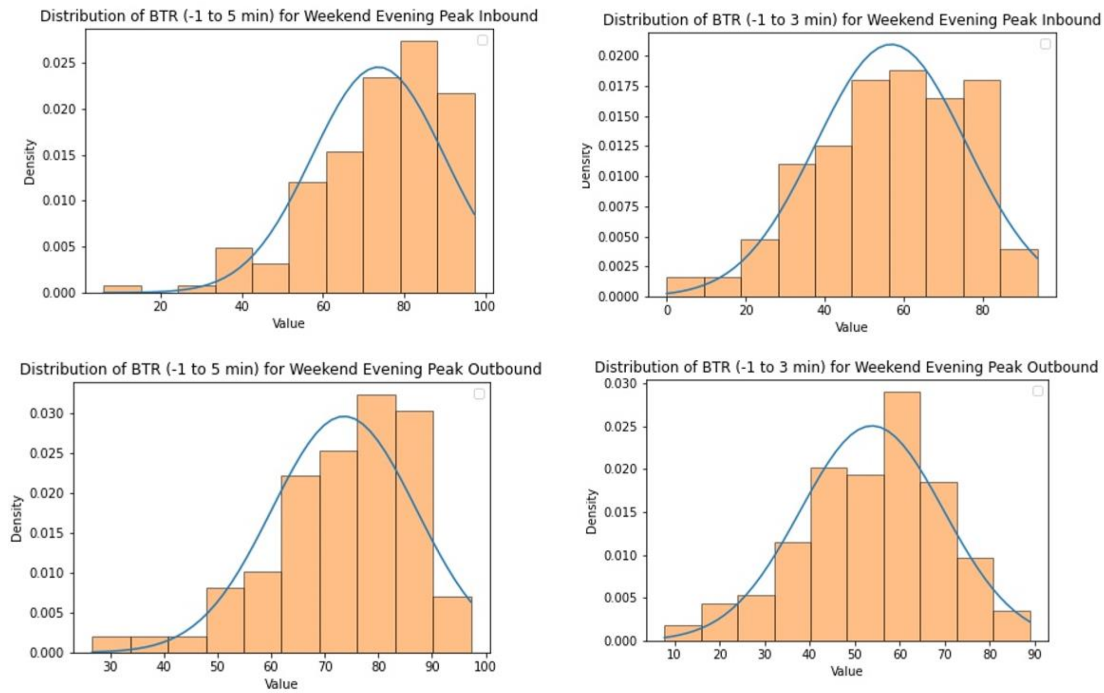

Figure B9 Distribution of bus transit reliability during evening peak hour on a weekend (inbound and outbound direction)

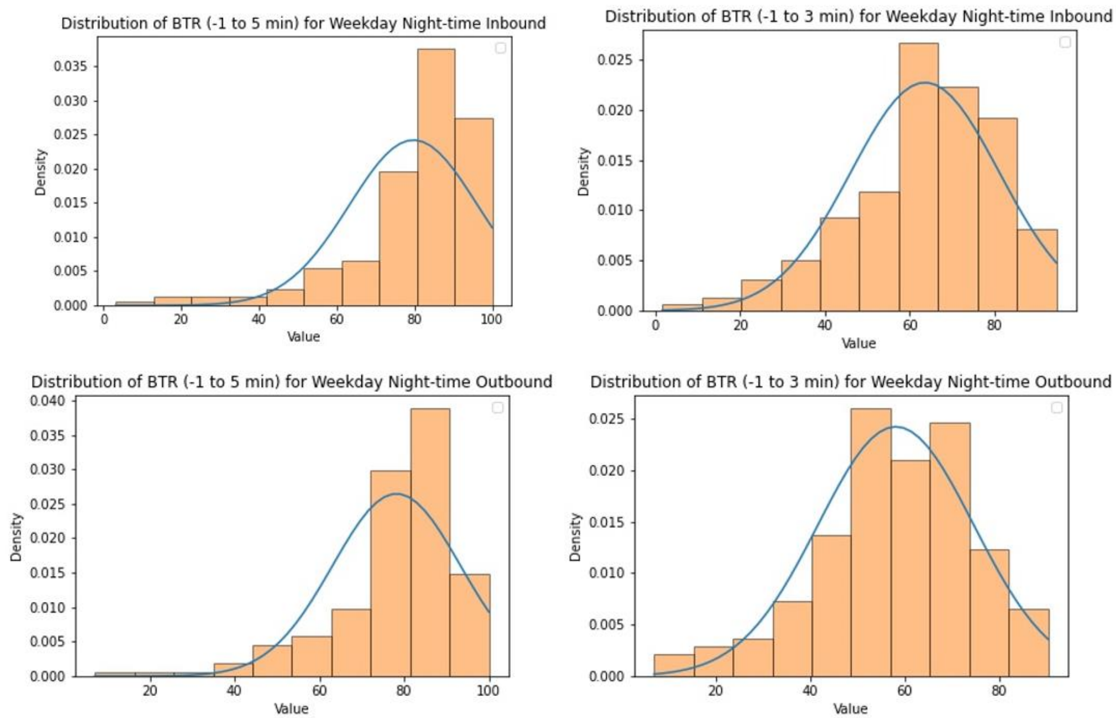

Figure B10 Distribution of bus transit reliability during night-time hour on a weekday (inbound and outbound direction)

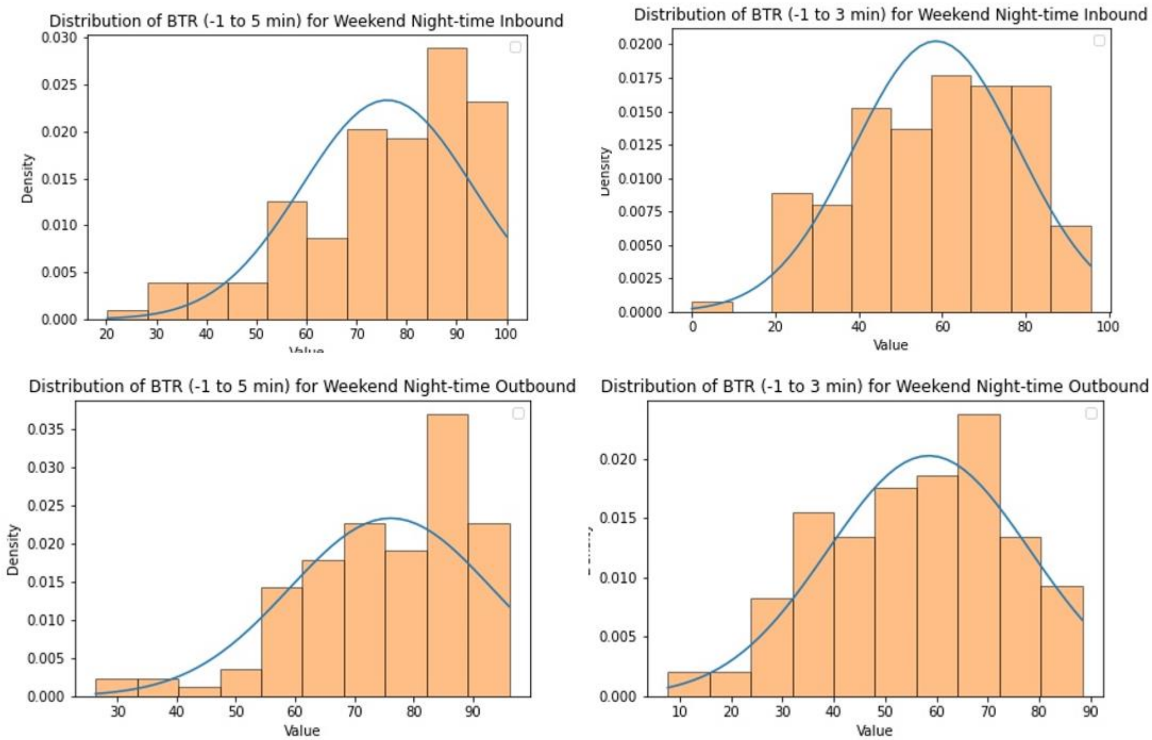

Figure B11 Distribution of bus transit reliability during night-time hour on a weekend (inbound and outbound direction)

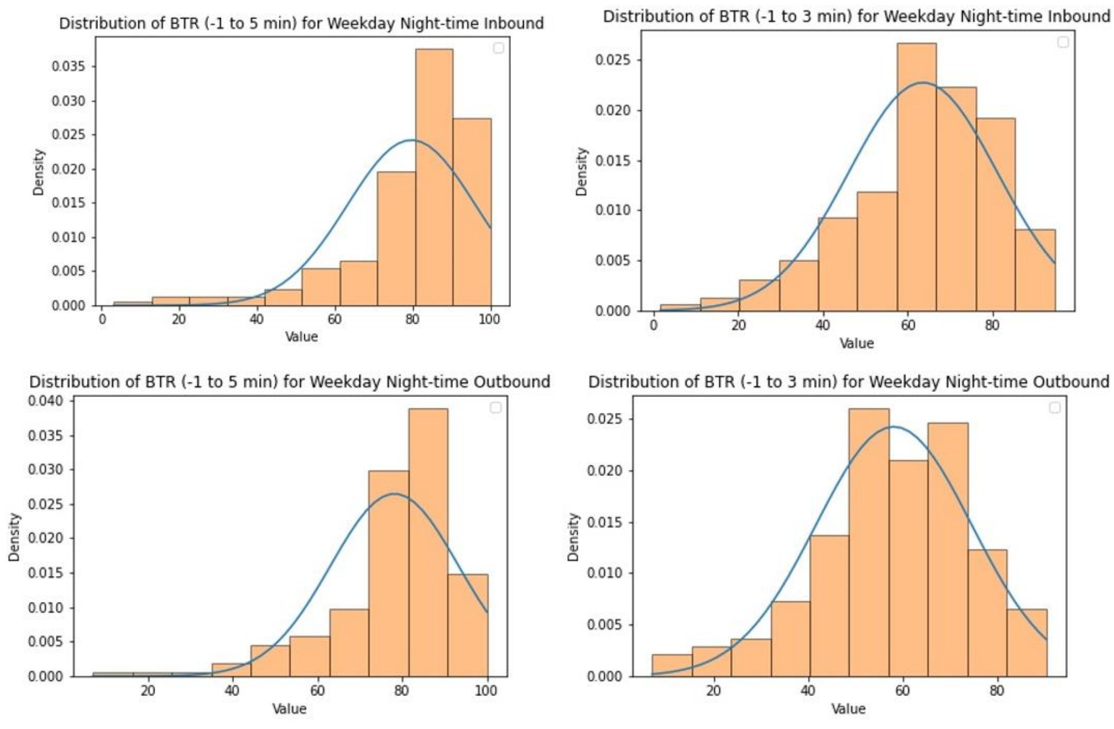

Figure B12 Distribution of bus transit reliability during night-time hour on a weekday (inbound and outbound direction)

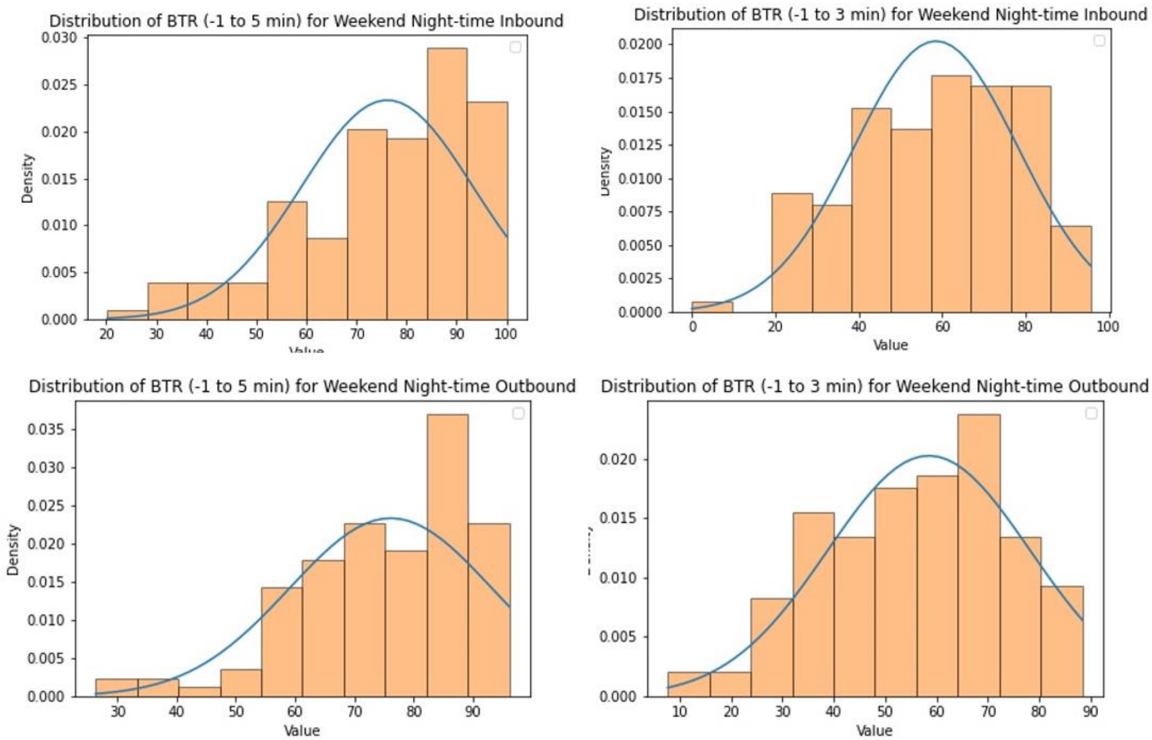

Figure B13 Distribution of bus transit reliability during night-time hour on a weekend (inbound and outbound direction)