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COLLEGE OF ENGINEERING

FACTORS AFFECTING BUS RIDERSHIP IN QATAR

BY

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ABSTRACT

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Title: Factors Affecting Bus Ridership in Qatar

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Traffic congestion is a major problem in Qatar where most of the population are car dependent. The purpose of this study is to understand the influence of various attributes on the system wide and stop level of public buses in Qatar. The study is divided into two parts, macroscopic and mesoscopic levels. In the macroscopic assessment, the study focuses on the bus system in Qatar and the factors affecting ridership, like the population, network expansion, and weather. On the mesoscopic level, the study focuses on factors affecting stop level ridership. A Multiple Linear Regression (MLR) model was developed to identify the parameters that significantly influence the stop level boarding and alighting. The results indicate that planning parameters especially those related to, personal business and shopping places, shopping commuters, restaurant commuters, residents, and number of restaurants are the main factors affecting the bus ridership.

This information can help policy makers and public authorities to develop policies and plans to increase the bus usage in the city. The study also investigates the impact of transit accessibility, and population and land use change on ridership. Furthermore, the developed framework can be applied to forecast ridership at potential new stop locations.

DEDICATION

I dedicate this work to my father (may his soul rest in peace), mother, wife and brothers and sisters and the whole family for their kindness and devotion

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I would like to express my deep appreciation to Dr. Khaled Shaaban, my research advisor, for his patient, guidance, enthusiastic encouragement and useful critiques of this research work.

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CHAPTER 1: INTRODUCTION

Qatar is one of the fastest growing countries in the world. Per records from the Ministry of Development Planning and Statistics (formerly the Statistics Authority), Qatar's population in 2004 was 744,029, and due to many factors, economic growth, oil and gas boom in the country, the population has grown up to 2,477,113 (300% increase when compared to 2004) (MDPS, 2016). This growth has resulted in a substantially larger private vehicle usage leading to congestion and major changes to the land use within the city of Doha as well as the inhabitants behavior and culture (Shaaban & Radwan, 2014) (Khalil & Shaaban, 2012). Based on Qatar Strategic Transport Model (QSTM) developed by the Ministry of Transport and Communication (MOTC), the public transport share (mainly Bus system) for the year 2018 is about 6.5% (MOTC, 2018).

To accommodate this growth and to reduce the private car usage in Qatar, the government has initiated the first Public Transport Company, named Mowasalat (KARWA). In 2005, Mowasalat has launched the first bus service with 5 routes and 15 buses, and untill 2008 the system was at its preliminary stages. In the 2nd quarter of 2008, Mowasalat has launched the Karwa Smart Card to manage the fare collection and service ridership. The smart card data is uploaded to a fare collection system called (Kentkart) that monitor the operation of the bus service and record the number of passengers and revenues per cardholder per line and stop. By the end of 2016, Mowasalat Bus Network was expanded to cover the entire State of Qatar with 51 lines and over 1100 stops (Figure 1). With this network, the current bus service is experiencing below expectations ridership (Mowasalat, 2017).

Figure 1: Bus Network in Qatar in year 2016

In addition, the country is experiencing a huge investment in the public transport infrastructure, by the development of the Metro system as well as Light Rail Transit systems (LRT) in Lusail City and Education City.

The objectives of this study were to investigate the bus ridership in the State of Qatar by: (1) assessment of the bus usage in the country, and (2) understanding the influence of various attributes on bus ridership in the State of Qatar.

The study provides a mechanism to understand the effect of the weather, population, network expansion and days of the week on the fluctuation of the ridershhip. In addition, it provides a mechnaism to assess the significance of the population groups and land use categories as well as the built infrastructure on bus ridership.. The results of the study can help policy makers and public authorities to develop policies and plans to increase the bus usage in the city.

The report is structured as the following:

- Chapter 2: Literature Review, where more details about the past studies used in the development of the methodologies followed in the current study.
- Chapter 3: Methodology and Data Collection, where this chapter focuses on the methodology and data collection for each part of the study.
- Chapter 4: Macroscopic Level Assessment. This chapter focuses on the analysis of the parameters and variables affecting the system-wide ridership over the country.

- Chapter 5: Mesoscopic Level Assessment. This chapter focuses on the analysis of the parameters and variables affecting the stop level ridership over the country.
- Chapter 6: Conclusion, recommendations, and study limitations.
- Chapter 7: References.

CHAPTER 2: LITERATURE REVIEW

For this research, the focus of the literature review was on the common public transport modes, like the metro, bus transit and light rail transit. The literature review was conducted, considering those modes, to capture the relevant parameters and analysis that can be reflected in this study as well as finding the gap to cover in the study. Furthermore, it was decided to not separate the literature review based on the transport mode, and instead, it is combined to maintain the integration of the ideas and avoid any confusion.

The use of different transport modes is affected by several factors such as the economic, sociological and geographical factors. To study the factors affecting the public transport ridership, many studies have examined the influence of several parameters within those categories on public transport ridership.

2.1. Factors Affecting Ridership

Arana et al. (Arana, et al., 2014) have studied the effect of weather and meteorological conditions on the public bus trips made for the purposes of leisure, shopping, and personal business. In this study, the statistics have shown that approximately 10% of trips are made by buses and over 30% are made by cars. However, the most preferred mode of transport as shown in the study was walking, with over 40% of trips. On the other hand, Li et al have assessed the fluctuation of weather conditions on metro ridership in China. For this study, Li et al. have employed the daily metro ridership data for three lines and conducted the statistical analysis against the fluctuation in the meteorological data for the city of the study. This study has been conducted for the period from June 2010 to June 2014 by studying the impact of temperature and precipitation. The study results demonstrated that the meteorological variables impact on the fluctuations of daily metro ridership results, in general, in a reduction on the number of passengers on individual lines and the overall transit network, especially on the weekends (Li, et al., 2017). Singhal et al. have examined the weather impact on the ridership considering a combination of days of week and time during the day. Singhal et al. have demonstrated that the climate's impact on transit ridership differs based on the time period and location. The study was conducted for years 2010 and 2011 and found out that the Manhattan subway has the greatest share of 2.9 million weekday trips in 2011. Those studies were mainly focusing on the geographical factors to examine their influence on public transit service (Singhal, et al., 2014).

Qin et al. have analyzed the bus choice behavior of car owners in middle-sized cities in China, as the car usage has grown up to over 20% leading to more congestion in the city (Qin, et al., 2013). In Istanbul, İmre & Çelebi have attempted to provide a better definition of comfort in public transport and developed a framework for measuring perception of comfort. With a population of 14 million, the number of passengers using the bus was approximately (3164) passengers per day. In this study, the authors have developed a composite index that can be used to quantify the comfort perception in public transport networks (İmre & Çelebi, 2017).

Ngoc et al. have conducted the study in Vietnam to understand the users' behavior in the developing countries, to predict the demand, and to suggest targeted motivating ways, services, and tools. The study aimed at examining customer's behavioral aspects while developing the quality standards and policies for public transport. It was found that the bus share in Vietnam in 2013 was approximately10%, while in Indonesia and Thailand the bus share was approximately 50% but decreased to 20-30% in 2013. In this study, the authors have identified specific aspects and developed a set of quality standards for public transport service in developing countries (Ngoc, et al., 2017).

Those studies have been materialized to develop the methodology for the Macroscopic Level Assessment by deriving the parameters that suit Qatar's case, and available upon the study.

For the second part of the study, a number of study have been conducted worldwide in the field of transportation focusing on promoting public transportation use. Most of those studies have focused on acquiring the understanding of the main factors affecting the usage of public transport system from two standpoints, the first is from the user perspective, and what makes people use transit mode. In this group, the focus is on examining the how people socio-demographic, accessibility measures and built environment and mainly infrastructure affect the use of transit mode. The second is from the transit system perspective, which focuses on the system level attributes affecting transit usage. In this group, the transit ridership is studied from the transit provider perspective (Chakour & Eluru, 2016) (Hu, et al., 2016) (Chakraborty & Mishra, 2013) (Kamruzzaman, et al., 2014) (Taylor, et al., 2009) and others.

A study by Kuby et al. was one of the studies focusing on the socioeconomic factors, where they have examined the influence of land use on the ridership. In this study, Kuby et al. have assessed the factors impacting the ridership of Light Rail Transit

System in the United States. These factors included the land use and network structure, in addition to several other parameters. The authors have assessed the population and employment densities and other parameters within the station walking distance against the LRT station boarding (Kuby, et al., 2004).

On the other hand, several studies have examined transit ridership to link the ridership with land use data, built environment, transit attributes, and socioeconomic characteristics etc. in various circumstances. Many researchers have focused on understanding the factors that are affecting the public transit ridership at a country-wide level. For example, Taylor et al. have conducted a countrywide research considering (265) urban areas in the United States and the study resulted that the ridership of a public transport system is mainly affected by the geography of the studied region, followed by the economy of the metropolitan area, the characteristics of the population, and the characteristics of the roadway system within that region. Taylor et al. have categorized the elements that might affect the ridership of a specific transit system as either internal, i.e. tariff, and level of service, or external, i.e. the variables of income, development, employment, parking policies, car ownership, fuel prices, and density levels. The study resulted that that external elements have, in general, a higher impact/influence on ridership than internal elements (Taylor, et al., 2009).

Numerous other researchers have focused on the land use impact and other parameters on the station level ridership (Chakour & Eluru, 2016) (Jun, et al., 2015), (Sung, et al., 2014) (Chakraborty & Mishra, 2013). For example, Sung et al. have investigated the influence of the following elements on rail transit ridership in Seoul and the metropolitan area in the vicinity of Seoul. These elements include land use, coverage of the rail service, and accessibility of the rail station. They employed the regression models to analyze the impact of land use by service coverage and the accessibility at the station-level on the ridership of the rail transit system. The relationship was empirically analyzed between rail transit ridership and locational characteristics of rail transit stations in terms of land use density and diversity, and station accessibility based on service distances of 250 m, 500 m, 750 m, 1 km, and 1.5 km. Overall, the findings confirmed that the 500m boundary for rail station service coverage is the best fit for rail transit ridership, which is empirically important when considering transit-oriented development. Furthermore, the results also demonstrated that spatial autocorrelation issues must be addressed for analyses of city- or regional-level transit ridership. Finally, the results identified development density and station-level accessibility as the most important measures for rail transit promotion (Sung, et al., 2014).

Chakour & Eluru have quantified the influence of operational attributes of the transit system, infrastructure attributes of the transportation system and the built environment attributes, on the boarding and alighting by the time of day of the disaggregate stop level for the bus transport system in the region of Montreal. The analysis of bus stop level boarding and alighting is undertaken by developing a Composite Marginal Likelihood (CML) ordered response model of the bus stop specific boarding and alighting hourly rates by time of day. The research involved measuring the effect of the built environment and urban design on the stop level ridership employing an ordered regression model. The authors have examined the ridership in different dimensions. First, considered three (3) stops levels based on the ridership as; high, medium, and low. For each of these, boarding and alighting were modeled separately. Further, each time period (Morning (AM) peak, Evening (PM) peak, Off-Peak day, Off-Peak night) was considered. Therefore, they have estimated an 8-dimensional multivariate ordered logit model using the CML approach for each category (low, medium and high). The final specification was based on a systematic process of removing statistically insignificant variables (Chakour & Eluru, 2016).

Many other authors have employed the land use and census data to find their impact on the transit ridership, for example, Johnson has employed the weekday transit boarding at bus stops of different routes and the census data as well as the land use data for the Minneapolis-St. Paul metropolitan region to examine the influence of socioeconomically data and land use, as well as the bus service, on the transit demand in the abovementioned cities. The study results suggested that there are three main ways to improve the ridership of any public transport system through proper planning of the land use, for example: (1) increasing the density of the residential land use in the vicinity of the transit corridors, (2) increase the mixed-use development within an eighth (1/8) mile of the transit corridors, and (3) allocate a higher portion of the retail development within a quarter (1/4) mile of the transit corridors (Johnson, 2003). While, Sun et al. have employed (100,000) points of interests (POIs) as the land use parameters within Beijing to catch the transit ridership by creating a multi-level catchment area combining the public transit with the walking, cycling, and bus trips, resulting in developing a synchronized public transport system (Sun, et al., 2016).

2.2. Catchment Area

In most of the research efforts conducted in the field of the public transport assessment, the catchment area was the common method to capture the relevant dependent variables affecting the transit ridership. Most of the public transit systems passengers are coming from areas in vicinity of the transit stops and not many are willing to walk for long distances, that explains the reason that the amount of public transport system passengers is proportional to the population densities living and working in the vicinity of the stops (Landex, et al., 2006).

It was obvious from the research that there are two methods to identify the catchment areas, the circular buffer and the service area, both methods are commonly used due to their applicability in any GIS platform. There is a debate on the benefit of each type, however, the application purpose can identify which one has to be used.

In Landex et al. paper, the authors have made a comparison between both types of catchment areas, and showed that the circular buffer approach reflects all locations within the stop's catchment area diameter, while the Service Area approach excludes locations because of the geographical surroundings and the detours that pedestrian must walk in the real street network. this has resulted to that the approach of circular buffer constantly overemphasizes the size of the catchment area and consequently the potential number of captured passengers (Landex, et al., 2006).

From the above comparison, it is clear that the service area was mainly used to capture the walking distance and accessibility to the stop ignoring all other parameters that shall be considered in the assessment of transit ridership. However, the following paragraphs will elaborate more on the commonly used catchment area method and how it has been used.

As clarified in the above paragraph, the selection of the catchment area depends mainly on the information that shall be captured, for example, Kamruzzaman et al. has used an 800 m buffer from the transit stop to derive the built environment indicators. The method used was the service area within the 800 m (Kamruzzaman, et al., 2014). On the other hand, many other types of research have implemented a circular buffer of different radius to conduct the study accordingly (Lee, et al., 2013) (Mishra, et al., 2012) (Vale, 2015) (Rodríguez, et al., 2009) (Estupin˜a´n & Rodrı´guez, 2008) (Sohn & Shim, 2010). The radius of each buffer varied due to the study area and transit system meant for the study. For example, Lee et al. have used 300 m buffer from the center of the transit stop in defining the catchment area to analyze the relationship between the metro ridership and the land-use patterns of the station areas (Lee, et al., 2013). A comparison between studies and the employed buffer/catchment area is presented in the following sections.

Table 1 lists the summary of all previous papers along with extra papers that have been used in this study but not been included in this section.

Table 1: Literature Review

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
1.	(Arana, et al., 2014)	Analyzing the influence of weather and meteorological conditions on bus trips made for the purposes of leisure, shopping and personal business in Gipuzkoa, Spain	Bus Transit	Bus Routes in a province (Gipuzkoa)	No Catchment Area	Average Daily Trips for two years. The focus was on Trips made for Leisure, and Shopping	• Rain • Temperature • Wind speed • Relative air humidity	2010 – 2011	Multiple Linear Regression	The study resulted in the following: • Wind and rain caused a reduction in the number of trips. • Temperatures rise caused an increase in the trips.
2.	(Li, et al., 2017)	The objective of this study is to assess the fluctuation in metro ridership caused by weather conditions in a city (Nanjing, China)	Metro System	Metro single line and network levels	No Catchment Area	Daily Metro Ridership	• Meteorological events • Precipitation and Precipitation values • Temperature	2011 – 2013	Analysis of Variance (ANOVA)	The study resulted in the following: • Negative meteorological parameters can cause a reduction in the daily mean ridership noticeably on the weekend. • Weekend trips are severely affected by the severe weather than weekday trips.
3.	(Zhou, et al., 2017)	Investigating the weather impact on public transport ridership as well as the travel behavior of individual public transport users.	Public Transit	System Level and Station Level	No Catchment Area	Daily average bus boarding Daily average metro ridership	• Temperature • Wind speed • Humidity • Rainfall • Air pressure	2014	Multivariate Regression Models	The study resulted in the following: • (System Level) The increase in the meteorological parameters like, humidity, wind, and the rainfall are related to a certain degree of transit ridership decrease • (Station Level) The increase in the humidity, wind, and the existence of rainfall have negative effects in many stations while positive effects appear in fewer stations.
4.	(Kuby, et al., 2004)	Quantify the effects of several factors on the average weekday boarding of existing light-rail stations in the US	Light Rail Transit	Station Level	Service Area within 800 m buffer	Average weekday boarding	• Employment • Population • Airport • International Boarder • College Enrollment • Park and Ride Spaces • Bus Connections • Other Rail lines • Heating and Colling Degrees • Normalized Accessibility • Primary Metropolitan Statistical	2000	Ordinary Least Squares Regression	The study resulted in the following: • The land use and accessibility are important. • Employment, population, and percent renters within walking distance, bus lines, park-and-ride spaces, and centrality, were significantly affecting the ridership.

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
							Area (PMSA) Population • Terminal Station • Station Spacing • Transfer Station • % of PMSA employment covered by the system • Percent Renters within walking distance.			• Dummy variables for terminal and transfer stations and international borders were significantly affecting the ridership. • Total degree-days were negative and significant, • lowering expectations for cities with extreme climates
5.	(Johnson, 2003)	Explain the the relationship between transit demand and factors influencing the demand including density, land use, socioeconomic characteristics, and transit service.	Bus Transit	Stop Level	No Catchment Area	Weekday Boarding	• Land Use Data • Density • Socioeconomic	2000	Linear Regression Analysis	The study resulted in the following: • Vertical mixed-use close to transit access is important. • Retail plays a significant role up to a quarter mile from transit service. • Population density is more important at a block-group level than block level. • Density adjacent to the line may not play a role as density in the larger surrounding area
6.	(Sun, et al., 2016)	Provide a quantitative link between land use and transit travel demand	Public Transit	Station Level	Multilevel Circular Catchment Area • Pedestrian Area: 770 m • Traffic Area: 3800 m The potential area is then determined using the Thiessen Polygon to define the area of influence around one sample point.	Average Daily Ridership	• Points of Interest (POI) • Resident Trip Survey • Land Use Type Built Up Area	2012	Multiple Regression Analysis	The Study resulted in the following: • The proposed model is simpler than the four-steps models. • Combining the ridership with precise land use data could serve as an important supplementary method in transit ridership forecasting and management
7.	(Zhuang, 2014)	• To develop a ridership model, • To test the generally accepted theory of land use/ridership relationship	Metro	Station Level	Circular Catchment Area of 800 m	Average Weekday Ridership	• Land Use • Income	• Land Use (2008) • Ridership (2008) • Income (2007-2011) • Metro Network (2012)	Ordinary Least Square Regression	The study resulted in the following: • Residential and commercial/office land use could be negatively correlated with ridership; • Los Angeles has a severe home/job imbalance around the rail stations; and

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
										• surrounding land use may not necessarily affect the stations' ridership.
8.	(Kamruzzaman, et al., 2014)	• To develop a typology for existing neighborhoods to understand the potential for different types of TODs in Brisbane, Australia; • To validate the typologies with performance indicators; and • To support the planning of advanced TOD typologies based on readily available policy indicators	Metro	Station Level	Service Area within a buffer of 800 m		• Physical Road Network • Cadastral Parcels with Land Use Classification • Public Transport Timetables • Census Data • Public Transport accessibility level • Net employment density • Net residential density • Land use diversity • Intersection density • Cul-de-sac density	• 2011	Multinomial Logistic Regression	Built environmental indicators offer a rigorous and quantitative approach to justify development decisions for TODs
9.	(Chakour & Eluru, 2016)	The objective of this paper is to quantify the influence of o the different variables on the stop level of a transit system.	Bus Transit	Stop Level	Various Circular Buffer Areas (200 m, 400 m, 600 m, 800 m, 1000 m). each catchment area is utilized to extract specific parameters.	• Boarding per hour • Alighting per hour	• Stop Headway • No. of Lines passing through the stop • Night buses passing through stops • No. of Bus Stops within buffer • No. of metro stations within buffer • No. of train stations within buffer • Bus Line length within buffer • Metro line in the TAZ • Train line length in the TAZ • Reserved bus lane length within buffer • Major roads length within buffer • Highway length within buffer • Park area within buffer • No. of parks within buffer • No. of commercial enterprises within buffer • Commercial area in the TAZ • Governmental and institutional area in the TAZ • Residential area in the TAZ • Park and recreational area in the TAZ • Resources and industrial area in the TAZ	• 2008	• Multivariate Linear Regression • Composite Marginal Likelihood (CML) based ordered response probit	The study resulted to the following: • The availability of metro stations, bus stops, and reserved bus lanes are positively significant. • The availability of parks is positively significant. • The availability of a highway has a negative impact. • The influence of the land use, specifically commercial area, government and institutional areas, and residential areas is temporally dependent. • The correlation results highlight the nature of unnoticed factors that might affect boarding and alighting during different time periods. • The elasticity analysis resulted that the most effective way to increase ridership is to increase public transport service and accessibility, whereas changes in land-

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
										use result in small increases in ridership.
10.	(Taylor, et al., 2009)	• Conduct a cross-sectional analysis of transit use in 265 urbanized areas, • test a wide array of variables measuring regional geography, metropolitan economy, population characteristics, auto/highway system • characteristics, and transit system characteristics, and • Construct two-stage regression models to account for simultaneity between transit service supply and consumption	Public Transit	System Level	No Catchment Area	• Ridership	Regional Geography • Area of urbanization • Employment concentration/dispersion • Metropolitan form /sprawl • Population • Population density • Regional location in the US • Regional topography/climate Metropolitan Economy • Unemployment levels • Gross regional product • Income distribution • Land rents/housing prices • Personal/household income • Sectoral composition of economy Population Characteristics • Age distribution • Percent of population in college • Percent of population in poverty • Percent of population recent immigrants • Political party affiliations • Racial/ethnic composition	• 2000	Ordinary Least Square Regression	
11.	(Lee, et al., 2013)	Verify that the ridership of transit stations at both ends of the range of urban structural hierarchy is more affected by density than by land use diversity, whereas the ridership of the stations in between are influenced more by land use diversity than by density	Metro	Station Level	500m	Ridership	• Density of Station Area • Mixed Use Index of Station Area • Intermodal Connectivity of Station Area Population	• 2010	Multiple Regression Analysis	The study resulted in the following: • Subway riders in the CBD station areas and the fringe areas or the periphery are influenced mostly by density, • Riders in the sub-central stations or the inner and outer suburbs are affected mainly by diversity. • Employment and shopping activities of CBD and sub-center overflow • The intermodal connectivity generally has the greatest influence on all station areas.
12.	(Hu, et al., 2016)	Evaluate the impact of Land Use on public transit ridership in both time and space	Public Transit	Stop and Station Levels	• 125 m, 250 m, 500 m for the bus stations. • 250 m, 500 m,	Ridership	• Time (t) • Land-use category density (L) • The satellite greenery data; Amenities density (A)		Three (3) different multivariate analytical methods to predict public	The study resulted in the following: • Amenity densities have various impact on

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
					and 1 km for the subway stations				transit ridership. (1) decision tree (DT), (2) support vector regression (SVR), (3) item-based collaborative filtering method (CF)	ridership during morning work-hours when a fixed routine is followed in going to work.
13.	(Rodríguez, et al., 2009)		Bus Transit		Circular buffer of 250 m	Pedestrian Count	• Bike path • Land use • Sidewalk buffer • Sidewalk continuity • Sidewalk width • Sidewalk quality • Benches • Trash Bins • Signage • Crossing aids • Vehicle obstructions • Density • Road density • Sum intersections • Homelessness • Stratum • UBN • Education • Violent deaths • Vehicle accidents • Thefts • Unemployment	June – August 2005	Poisson and negative binomial models	The study resulted that connectivity, pedestrian-friendly amenities, land uses, and crossing aids are related to a higher pedestrian count.
14.	(Estupin˜a´n & Rodrı´guez, 2008)	Examining the built environment characteristics on Bus stop-level ridership	Bus Transit	Stop Level	• Circular buffer of 250 m	Number of daily boarding	• Alternative Number of bus transit • Presence of a bus feeder service • Number of routes served by a station • Type of station • Number of vehicles per day per station • Bikepath • Land Use • Buffer width between sidewalk and road • Traffic control • Sidewalk continuity • Sidewalk width • Sidewalk quality • Amenities • Safety • Perception of Cleanliness • Perception of pedestrian	• 2005 • 2006	Generalized Method of Moments (GMM) estimator	The study resulted in the following: • Built environment attributes, crosswalk and sidewalk, have high impact on the BRT boarding. • High density and Land Use mix have less impact but still affecting the BRT boarding.

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
							friendliness • Perception of bike friendliness • Overall perception • Density • Stratum • Road_density • intersections • NBI • Schooling • Violent_deaths • Crashes • Thefts • Unemployment			
15.	(Vale, 2015)	Evaluate the urban design features of the station areas, in particular their pedestrian friendliness	Metro System	Station Level	• Service Area within a buffer of 700 m	• Directions served by train and/or ferry • Daily frequency of train and/or ferry services • No. of stations within 20 min of travel • No. of directions served by other public transport • Daily frequency of services by other public transport • Distance from the closest motorway access • Car parking capacity • No. of residents • No. of workers in retail/hotel and catering • No. of workers in education/health/culture • No. of workers in administration and services • No. of workers in industry and distribution • Degree of functional mix				The study resulted that a balanced node-place is not necessarily a transit-oriented development, and vice versa,
16.	(Kalaanidhi & Gunasekaran, 2013)	Evaluate the impact on ridership for changes in the Accessibility Indices due to variation in bus transit fare and travel time	Bus Transit	Stop Level	Not defined	Boarding and Alighting	• Population • Accessibility Index	2007 data was uplifted with growth factor (8%) to project to year 2013	Multiple Linear Regression	The study resulted that the waiting time at the bus stops has relatively greater impact on Accessibility Indices than off-vehicle travel cost
17.	(Sohn & Shim, 2010)	An investigation into the factors affecting Metro demand at a station level	Metro	Station Level	500 m	Average weekday boarding at stations	• Population within walking distance • Employment within walking distance • Dummy variable to indicate if a university is adjacent to stations • Total floor area of residential buildings within walking distance • Total floor area of office buildings within walking distance • Total floor area of commercial buildings within walking distance • Total floor area of other-use buildings within walking distance • Land-use diversity index • Total length of automobile-dominated roads		• Multiple regression analysis and • Structural equation model (SEM)	The regression analysis resulted that seven variables are significantly associated with station boarding, these are: employment, commercial floor area, office floor area, net population density, number of transfers, number of feeder bus lines, and a dummy variable indicating transfer stations.

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
							• The number of dead end points at which pedestrian-friendly streets are blocked • The number of intersections crossed by only pedestrian-friendly streets • The ratio of population to unit residential floor area • Closeness index calculated based on Metro network • Betweenness index calculated based on Metro network • Straightness index calculated based on Metro network • Closeness calculated based on highway network • Betweenness index calculated based on highway network • Straightness index calculated based on highway network • The average number of transfers across the itinerary from a station to all other stations • The average distance on Metro network from a station to five city centers • The number of feeder bus lines stopping at a station • The number of trunk bus lines stopping at a station • Dummy variable to indicate if a station belongs to the group of transfer stations • The number of Metro lines passing at stations			
18.	(Chakraborty & Mishra, 2013)	Establish the connections between transit ridership and land use and socioeconomic variables, and project future ridership under different scenarios	Public Transit	Systemwide	Not defined	Daily transit ridership	• Household density • Population density • Household workers density • Total employment density • Retail employment density • Office employment density • Industrial employment density • Other employment density • Drive alone density • Household with 0 cars • Income less than 20,000 • Income between 20,000 and 40,000 • Income between 40,000 and 60,000 • Income between 60,000 and 100,000	2000	Ordinary least squares (OLS) and Spatial error model (SEM)	Estimating transit ridership under multiple scenarios showed the following: • Demand can vary by parts of the state • Demand demonstrates the model's value in assessing transit and land use planning decisions

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
							• Income over 100,000 • Total school enrollment • Total freeway distance • Average free flow speed • Accessibility to transit (dummy variable) • Dinning square feet • Healthcare square feet • Housing square feet • Industry square feet • Office square feet • Recreation square feet • Shopping square feet • Warehouse square feet			
19.	(Yetiskul & Senbil, 2012)	Quantify and determine the under lying determinants of public bus transit travel-time variability using data collected in Turkey's capital of Ankara	Bus Transit	Systemwide	Not defined	Average number of passengers	• Time of Day • Network Expansion	2009-2010		The characteristics of operational regions, highways, time of day and time of week will produce significant gains in transit reliability.
20.	(Sung, et al., 2014)	Investigate the impacts of land use, rail service coverage, and rail station accessibility on rail transit ridership in the city of Seoul and the surrounding metropolitan region.	Metro	Station Level	250 m 500 m 750 m 1 km 1.5 km	Average number of daily riders by station	• Land Use Density including residential, offices, commercial and public service within defined catchment areas • Diversity • No. of Station entry/exit • No. of Bus Routes • Distance to the nearest station • Transfer station • Railway type • Distance to regional stations	2010	Ordinary Least Square Regression	The Study resulted in the following: • Rail transit service coverage boundary of 500 m provides the best fit for estimating rail transit ridership levels. • Density is positively related to rail transit ridership within a 750 m radius of each station. • Land use diversity is not associated with rail transit ridership. • Station-level accessibility is as important as land use for explaining rail transit ridership levels. • Development density and station-level accessibility measures such as the number of station entrances or exits and the number of bus routes at the station are the most important and consistent factors for promoting rail transit ridership.

No.	Author (Citation) and Journal Name	Objectives	Public Transit System	Study Level	Catchment Area	Dependent Variables	Independent Variables	Study Period	Statistical Analysis	Results
21.	(Ngoc, et al., 2017)	Examine the Customers' behavioral aspects while developing the standards for public transport services.	Bus Transit	Systemwide	Not defined	Overall Satisfaction	• Bus comfort • Safety • Security • Stop Comfort • Accessibility for disabled people • Walking Distance and Environment • Driver Behavior • Seating • Cleanliness • Network Coverage • Span of Service • Frequency • Fare • Punctuality • Travel Time	July 2013 with a sample of 280 inhabitants	Multiple Regression Analysis	The study resulted in the following: • Safety, security, span of service, and stop comfort were rated as the highest important criteria in both motorcycle users and bus users. • Punctuality, frequency, bus comfort, cleanliness and accessibility for disabled persons were ranked as the second most important criteria.

It is obvious from the literature review above, that the land use impact on the ridership was extensively employed in the research. Most of the land use parameters used are related to either areas or densities, population and employment only in addition to census data. The gap that has been covered in this study can be summarized in the following points:

1. The utilization of the trip based population structure as well as points of interests (POIs) as factors representing the land use parameters affecting the ridership.
2. None of the studies with similar characteristics was conducted in the region and specifically in the State of Qatar.
3. Limited studies had covered a systemwide in a country with various levels in one study.
4. Limited studies combining both the weather and land use impacts on the fluctuation of the ridership in one study.

CHAPTER 3: METHODOLOGY AND DATA COLLECTION

3.1. Introduction

As briefly described in Chapter 1, in 2005 Mowasalat has launched the first bus service with 5 routes and 15 buses, and till 2008 the system was in its preliminary stages. In the 2nd quarter of 2008, Mowasalat has launched the Karwa Smart Card to manage the fare collection and service ridership. The smart card data is uploaded to a fare collection system called (Kentkart) that monitor the operation of the bus service and record the number of passengers and revenues per cardholder per line and stop. By the end of 2016, Mowasalat Bus Network was expanded to cover the entire State of Qatar with 51 lines and over 1100 stops. With this network, the current bus service is experiencing below expectations ridership (Mowasalat, 2017).

Figure 2 illustrates the development timeline of Mowasalat (Karwa) services including the bus service in Qatar. The expansion of the bus service started mainly once the Karwa Smart Card initiated and became officially in use.

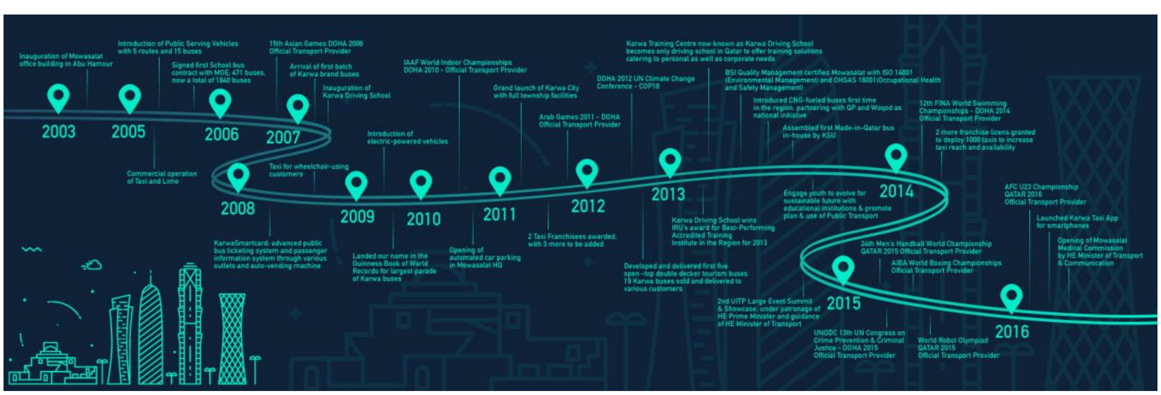


Figure 2: Mowasalat Development Timeline

The study has been divided into two major parts, as clarified earlier, to understand the various factors on different levels on the bus ridership. In the first part, the study is covering the entire network to assess the bus usage in the country at the network level for the period from 2012 – 2016, this part is called the Macroscopic Level Assessment. In the second part, the study is also covering the entire network but to the stop level ridership. This assessment is to identify what are the main factors that affect the stop level ridership for year 2016 (Mesoscopic Level Assessment).

The following sections will elaborate the scope of each part, the methodology, and the data needed to conduct the assessment.

3.2. Macroscopic Level Assessment

The fluctuation in bus ridership can be a result of several factors such as population, land use, network expansion, days of the week, seasons and/or weather parameters.

The purpose of the Macroscopic Level Assessment part of the study is to elaborate a range of factors causing the fluctuation of the ridership over the entire network in Qatar. The overall network from year 2012 to 2016 was considered and several parameters have been assessed against the route's ridership. More details about the selection of the study period as well as limitations will be presented at the end of this chapter.

3.2.1. Data Collection

Several agencies and official websites have been approached and visited as well as personal interviews to collect the relevant data for this approach. For example, the bus ridership data was collected from Mowasalat through the KentKart Fare Collection System launched by Mowasalat in 2008. Table 2 list all parameters used in the analysis and their definitions and sources.

Table 2: List of Parameters used in the Macroscopic Approach

Parameters	Units
Daily Ridership	Sum of total daily ridership over the study period (sum of boarding and alighting) (Mowasalat, 2017).
Total Monthly Ridership	Sum of the daily ridership per month over the study period.
Average Monthly Ridership	Average daily ridership per month over the study period.
Weekdays	Days of the week other than Fridays (Saturday – Thursday).
Total Weekdays Ridership	Sum of daily ridership over weekdays.
Average Weekdays Ridership	Average daily ridership over weekdays.
Weekends	Fridays in the study period. Please refer to section.
Total Weekends Ridership	Sum of daily ridership over Weekends.
Average Weekends Ridership	Average daily ridership over Weekends.
No. of Lines	Number of Lines/Routes for the entire Network per year in the State of Qatar (Mowasalat, 2017).
Weather Data	Official Weather Data (Qatar Meteorology Department, 2017) and (WeatherSpark, 2017)
Temperature (ºC)	Official Temperature in the Country per day and month (average, maximum and minimum) (Qatar Meteorology Department, 2017)

Parameters	Units
Precipitation (%)	The percentage of days in which rainfall is observed, excluding trace quantities. (WeatherSpark, 2017)
Rainfall (mm)	Total rainfall accumulated. (Qatar Meteorology Department, 2017)
Relative Humidity (%)	Mean Relative Humidity at the county (Qatar Meteorology Department, 2017). Relative humidity can be defined as the ratio of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated hour. (National Oceanic and Atmospheric Administration's , 2017)
Population	The official population of Qatar per year over the period from 2012 – 2016 (MDPS, 2016)

3.2.2. Methodology

To develop a clear methodology to conduct the Macroscopic Level Assessment, an extensive research has been conducted. The research has covered several approaches including the assessment of the impact of the number of lines on the ridership (Liu, et al., 2017), the impact of weekdays and weekends on the fluctuation of ridership (Yetiskul & Senbil, 2012), and the most important one is the impact of weather on the fluctuation of the ridership (Arana, et al., 2014) (Li, et al., 2017). The analysis and results are presented in Chapter 3 of this report.

3.2.2.1. Ridership vs. Number of Lines

Liu et al have assessed the impacts of new lines on passenger flow of existing stations to the metro network in Guangzhou-China. In the assessment, Liu et al. have considered the daily entrance passenger flow to calculate the monthly average daily passenger flow of each station from January 2011 to September 2014 (Liu, et al., 2017).

In this study, the assessment level was not to station level, and instead, the entire bus network was considered due to lack of data related to exact network expansion. The daily ridership of the entire network from the year 2012 to 2016 was employed in the assessment. The relation between the ridership and the number of lines will be drawn for visualization purposed only.

3.2.2.2. Ridership vs. Weekdays and Weekends

The daily ridership from year 2012 to year 2016 have been again considered to calculate the weekdays and weekends total and average ridership. The overall ridership has been collected from the Kentkart fare collection system of Mowasalat and compiled in a spreadsheet to visualize the trend and fluctuation of the ridership over the weekdays and weekends.

It is worth noting that Mowasalat used to have two timetables for the bus network operation, one for the weekdays from Saturday to Thursday, and the other for the weekends which includes only Fridays. This is incompatible with the official workdays and weekends in the country, however, in the assessment, the weekends have been considered like the Mowasalat definition and Fridays only were considered as weekends (Mowasalat, 2017).

3.2.2.3. Ridership and Weather

In Qatar, the weather plays a significant role in affecting people behavior and mode choice, due to the extremely hot temperature during the summer and the moderate temperature during winter. However, the pleasant weather starts on November till March every year, with a maximum temperature of $29^{o}C$ and a minimum temperature of $14^{o}C$.

While the summer starts on May until September with a maximum temperature of 39^{o}C and a minimum temperature of 27^{o}C. The summer season is long, sweltering, muggy and arid, and the winters are comfortable, dry, windy, and mostly clear.

3.3. Mesoscopic Level Assessment

The Mesoscopic Level Assessment was conducted to understand the characteristics of the users based on the land use categories and their origin and destination, and to understand the influence of various attributes on the stop level. For that purposes, several authors' methodologies have been followed to alter a good methodology that fits with Qatar conditions and match with the collected data (Chakour & Eluru, 2016) (Taylor, et al., 2009) (Zhao, et al., 2013). Those methodologies have been followed with some modifications due to constraints in collecting data as will be presented in the Study Limitations Section at the end of this report.

3.3.1. Data Collection

To identify the necessary period for the analysis, an extensive literature review has been conducted to identify the suitable boarding and alighting period for Qatar study. Table 3 shows the comparison between the relevant papers and the selected period in the study which has been included in the literature review summary in Chapter 2 and Table 1.

Based on the past studies, most of the studies have utilized the average daily and average weekday ridership of boarding and alighting, while limited papers have utilized the total daily per year ridership. Accordingly, it was decided to use the total and average daily boarding and alighting, total and average weekday and weekend boarding and alighting. Table 4 tabulates the dependent variables used in the study with their definitions and units.

3.3.1.1. Dependent Variables:

As presented in Table 3, many authors have employed the Boarding and Alighting in the peak and off-peak periods along the day, however, in the current study, the dependent variables are the boarding and alighting in daily, weekday, weekends, monthly and yearly bases. The boarding and alighting data have been collected from Mowasalat Official Fare Collection System (KentKart) for the year 2016.

Table 3: Literature Review for Study Period Selection

Author	System	Data Used	Operation	Level
Kuby et al. (Kuby, et al., 2004)	LRT	Average Weekday	Boarding	Stop Level
Sun et al. (Sun, et al., 2016)	Transit	Average Daily	Boarding/Alighting	Station Level
Zhuang (Zhuang, 2014)	Metro	Average Weekday	Ridership (Total Boarding and Alighting)	Station Level
Zhou et al. (Zhou, et al., 2017)	Transit	Average Daily	Ridership (Total Boarding and Alighting)	Station Level
Chakrabarti (Chakrabarti, 2015)	Metro Bus	Average per hour	Boarding	Stop Level
Jun et al. (Jun, et al., 2015)	Subway	Daily	Ridership (Total Boarding and Alighting)	Stop Level
Chiang et al. (Chiang, et al., 2011)	Transit	Monthly	Ridership (Total Boarding and Alighting)	Stop Level
Estupin˜a´n & Rodrı´guez (Estupin˜a´n & Rodrı´guez, 2008)	BRT	Daily	Boarding	Stop Level
Kalaanidhi & Gunasekaran (Kalaanidhi & Gunasekaran, 2013)	Bus	Daily	Boarding/Alighting	Stop Level
Chakour & Eluru (Chakour & Eluru, 2016)	Bus	Hourly	Boarding/Alighting	Stop Level
Sohn & Shim (Sohn & Shim, 2010)	Metro	Average Weekday	Boarding	Station Level
Chakraborty & Mishra (Chakraborty & Mishra, 2013)	Transit	Daily	Ridership (Total Boarding and Alighting)	Statewide Level
Sung et al. (Sung, et al., 2014)	Rail	Average Daily	Ridership (Total Boarding and Alighting)	Station Level
Zhao et al (Zhao, et al., 2013)	Metro	Annual Average	Ridership (Total Boarding and	Station Level

Author	System	Data Used	Operation	Level
		Weekday	Alighting)	
Brakewood et al. (Brakewood, et al., 2015)	Bus	Average Weekday	Ridership (Total Boarding and Alighting)	Route Level
Ryan & Frank (Ryan & Frank, 2009)	Bus	Total Daily per Year	Boarding and Alighting	Stop Level
Debrezion et al. (Debrezion, et al., 2009)	Rail	Total Daily per Year	Ridership	Station Level
Transportation Research Board (Transportation Research Board, 2007)	Transit	Total Daily per Year	Ridership	Systemwide Level

Table 4 List of Dependent Variables used in the Mesoscopic Approach

Type	Parameters	Definition
Bus Data (Dependent Variables)	Average Hourly Boarding	Average Number of Passengers Boarding Hourly (2016)
	Total Daily Boarding	Total Number of Passengers Boarding Daily (2016)
	Average Daily Boarding	Average Number of Passengers Boarding Daily (2016)
	Total Weekday Boarding	Total Number of Passengers Boarding on Weekdays (2016)
	Average Weekday Boarding	Average Number of Passengers Boarding on Weekdays (2016)
	Total Weekend Boarding	Total Number of Passengers Boarding on Weekends (2016)
	Average Weekend Boarding	Average Number of Passengers Boarding on Weekends (2016)
	Average Hourly Alighting	Average Number of Passengers Alighting Hourly (2016)
	Total Daily Alighting	Average Number of Passengers Alighting Hourly (2016)
	Average Daily Alighting	Total Number of Passengers Alighting Daily (2016)
	Total Weekday Alighting	Average Number of Passengers Alighting Daily (2016)
	Average Weekday Alighting	Total Number of Passengers Alighting on Weekdays (2016)

Type	Parameters	Definition
	Total Weekend Alighting	Average Number of Passengers Alighting on Weekdays (2016)
	Average Weekend Alighting	Total Number of Passengers Alighting on Weekends (2016)

3.3.1.2. Independent Variables:

The independent variables were driven from several papers (Chakour & Eluru, 2016) (Taylor, et al., 2009) (Zhao, et al., 2013). The reason for that was due to the availability of data in the approached entities. The employed independent variables are listed in Table 5.

Table 5: List of Independent Variables used in the Mesoscopic Approach

Type	Parameters	Definition
Infrastructure Data (Independent Variables)	Road Length (m)	Length of Roads within Catchment Area
	Footpath (m^2)	Area of footpath within Catchment Area
	Bike Lane (m^2)	Area of Bike Lane within Catchment Area
	Parking (m^2)	Area of Parking within Catchment Area
Population per Activity and Land Use and Points of Interests (Independent Variables)	Employer Business (Number)	Number of persons available within the catchment areas attracted for work-related business.
	Employees	Number of employees available within the catchment area.
	Leisure Commuters	Number of persons available within the catchment areas attracted for leisure purposes (hotels, hospitality, etc.)

Type	Parameters	Definition
	Mosques	Number of Mosques (buildings) within the catchment area.
	Personal Business	Number of persons available within the catchment areas for personal related business.
	Adults	Population (over 5 years old) available within the catchment areas.
	Number of Restaurants	Number of Restaurants within the catchment area.
	Restaurants	Number of persons within catchment areas for restaurants.
	Number of Schools	Number of Schools within the catchment area.
	Schools Students	Number of school students within the catchment areas that include a school in the land use category
	University	Number of university students within the catchment areas that include a university in the land use category.
	Shopping Places	Number of Shopping Places within catchment area.
	Shopping	Number of persons within catchment areas for shopping purposes
	Total Population	Total Population within the catchment area.

3.3.2. Catchment Area

Based on past studies, a circular buffer of 500m was selected to capture the relevant independent variables in the vicinity of the bus stop. The selection of the type (circular buffer) and size of the catchment area (500m) was based on literature review done earlier as shown in Table 1 and summarized in Table 6. Furthermore, the selection of the catchment area type was based on the type of the study, where the study is meant to measure the availability of the relevant variables within the catchment area.

Table 6: Literature Review for Catchment Area Selection

No.	Paper Title	Catchment Area
1.	Sohn & Shim (Sohn & Shim, 2010)	500 m
2.	Chakour & Eluru (Chakour & Eluru, 2016)	200, 400, 600, 800, 1000 m
3.	Zhao et al. (Zhao, et al., 2013)	800 m
4.	Rodríguez et al (Rodríguez, et al., 2009)	250 m
5.	Kuby et al. (Kuby, et al., 2004)	800 m
6.	Sung et al. (Sung, et al., 2014)	250, 500, 750, 1000, 1500 m
7.	Chakraborty & Mishra (Chakraborty & Mishra, 2013)	800 m
8.	Lee et al. (Lee, et al., 2013)	500 m
9.	Mishra et al. (Mishra, et al., 2012)	800 m
10.	Hu et al. (Hu, et al., 2016)	Bus Stations: 125, 250, 500 Subway Stations: 250, 500, 1000

After identifying the catchment area size, a Geographic Information System (GIS) map was created. The layers have been collected from the sources in a GIS (Shapefile) format. This allowed the study team to have layers that are georeferenced to Qatar official datum. These layers are listed in Table 7.

Table 7: GIS Layers and Sources

Layer	Purpose	Source
Bus Lines	To identify the routes and allocate the stops	Mowasalat
Bus Stops	To identify the Bus Stops along each route and identify the origin of the catchment area.	Mowasalat
Road Flowline	To measure the length of the road within the catchment area	Ashghal and Ministry of Municipality and Environment (MME)
Footpath	To measure the sidewalks area within the catchment area	Ashghal and Ministry of Municipality and Environment (MME)
Bicycle Lane	To measure the available bicycle lanes area within the catchment area.	Ashghal and Ministry of Municipality and Environment (MME)
Parking	To measure the sidewalks area within the catchment area	Ashghal and Ministry of Municipality and Environment (MME)
EXP TAZ Land use 2016 zone	To capture the population groups per activity included in the zones within the catchment area.	Ministry of Transport and Communications (MOTC)
Points of Interest (POI)	To capture the number of places within the catchment area, Schools, Shopping Places, Mosques, and Restaurants	Ministry of Municipality and Environment (MME)

Figure 3 illustrates the GIS map and the overlaid layers utilized for the data. The top map included the infrastructure layers (Road, Footpath, Parking and Bike Lanes), Land Use layer including all relevant land use and the corresponding population groups as well as the points of interests. Bus Routes and Stops are presented. A buffer of 500m was then developed around each bus stop to create the catchment area.

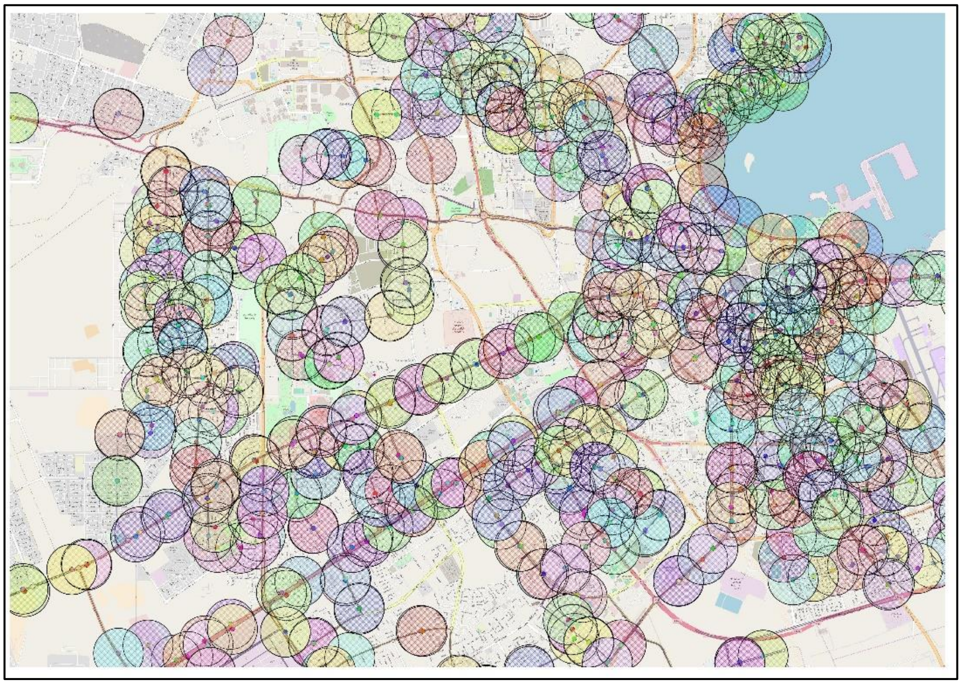


Figure 3: GIS Map with all layers and catchment areas

3.3.3. Methodology

As clarified earlier, this study will contribute to the literature as the following: first, the employment of boarding and alighting at different time periods, second, the utilization of the activity based population structure as well as points of interests (POIs) as independent factors affecting ridership, third, conducting the study in a developing country specifically in the State of Qatar.

The 2016 bus network comprises of 51 bus routes with 1146 bus stops spread over the country. In this part of the study, the entire network and stops are considered, the daily boarding and alighting data have been collected and calculations related to the same has been conducted and compiled.

The trend of boarding and alighting was analyzed to identify the peak days of the week and months during the year 2016. In addition, the list of parameters along with the boarding and alighting as presented previously were extracted to evaluate the correlation between them and conduct the statistical analysis accordingly.

Multiple linear regression models were developed, with a prediction goal, to estimate boarding and alighting on different levels based on the bus infrastructure, population, and planning-related attributes. Multiple Linear Regression (MLR) analysis was chosen as it is a robust technique that can model the effect of continuous and categorical variables. The mathematical formulation of MLR model and various measures is shown in Equations 1 to 8. The analysis was conducted using a confidence interval of 95%.

MLR for the complete model,

$$Y = \beta_o + \beta_1 \times x_1 + \beta_2 \times x_2 + \cdots + \beta_p \times x_p + \cdots + \beta_k \times x_k + E \quad \text{Equation 1}$$

Then R^2 will be:

$$R_p^2 = 1 - {}^{SSE_p}\!/_{SSY} \quad \text{Equation 2}$$

$$R_{Adj}^2 = 1 - \left[\frac{(1-R^2)\times(n-1)}{(n-p-1)}\right] \quad \text{Equation 3}$$

$$SSY = \sum_{i=1}^{n}(y_i - \bar{y})^2 \quad \text{Equation 4}$$

Where:

$SSE(p)$ = error sum of squares of model with p variables

SSY = Total (corrected) sum of squares for the response Y

n = total number of observations

p = no of variables in sthe elected model

k = total number of variables considered in the maximum model

R_k^2 = Predictive ability of model with k variables

R_p^2 = Predictive ability of model with p variables

CHAPTER 4: MACROSCOPIC LEVEL ASSESSMENT

4.1. Introduction

The purpose of the Macroscopic Level Assessment is to focus on a range of factors causing the fluctuation of the ridership over the entire network in Qatar. The overall network as well as the ridership from year 2012 to 2016 were considered and several parameters have been assessed against the ridership.

4.2. Ridership per year

In this section, the variation in the number of passengers was assessed over the period from the year 2012 to 2016.

Table 8: Number of passengers per year

Years	Total Number of Passengers per Year	Average Number of Passengers per year
2012	10,844,066	29,629
2013	11,739,717	32,164
2014	10,606,154	29,058
2015	10,594,215	29,025
2016	12,711,621	34,731

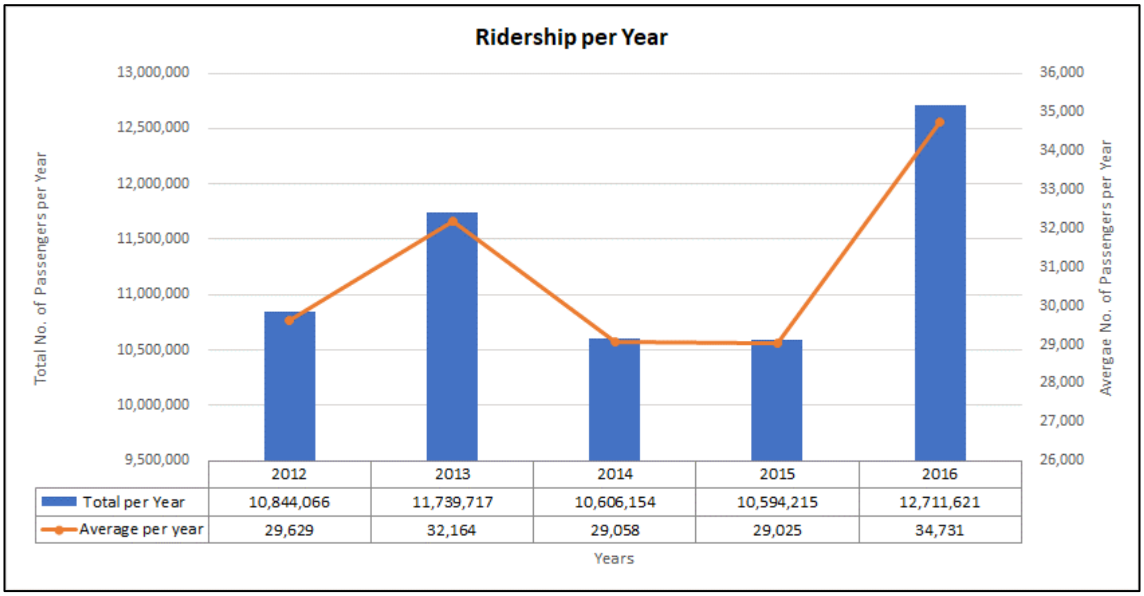


Figure 4: Trend of changes in passengers' counts per year

From Table 8 and Figure 4, the ridership has gradually increased from the year 2012 to 2013, but dropped in 2014 and 2015 then increased to its highest in 2016.

The variation in the ridership could be affected by different variables, for example, the number of lines, number of stops, population, weather or any other factors, however, to highlight the effect of the variables, further analysis against the following parameters have been conducted:

- Population
- Network expansion
- Day of the week
- Weather

4.2.1. Ridership vs. Population

As presented earlier in the Data Collection section, the population data was collected from the official website for the Ministry of Development Planning and Statistics (MDPS, 2016). The population in the State of Qatar during December 2017 has reached (2,641,669), which shows the rapid growth in the country if compared with the population in December 2016 (2,597,453). In years 2010 and 2015 (MDPS, 2016) has conducted detailed censuses of the population in Qatar.

By studying the influence of population variation on the ridership, the results are outlined in Table 9 .

Table 9: Ridership vs. Population

Years	Ridership	Population	Ridership/Passenger/Year
2012	10,844,066	1,832,903	5.916
2013	11,739,717	2,003,700	5.859
2014	10,606,154	2,216,180	4.786
2015	10,594,215	2,404,776	4.405
2016	12,711,621	2,617,634	4.856

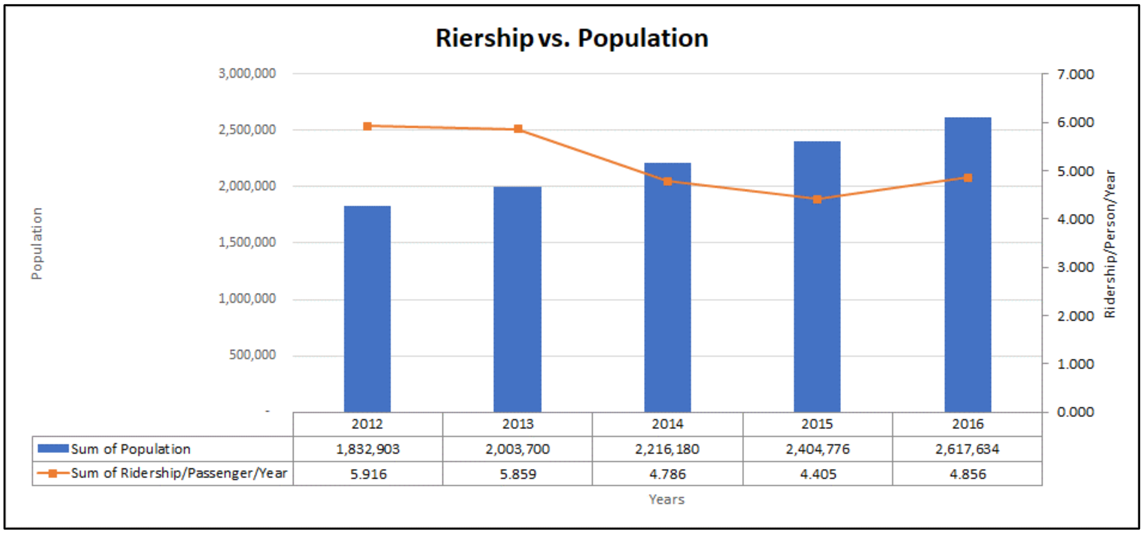


Figure 5: Trend of changes in ridership against population

The population had a diverse impact on the ridership, and instead of having an increase in the ridership along with the population, it was surprisingly decreasing starting in 2014 to its lowest in 2015 and increased again in 2016 (Figure 5). To clearly assess the population impact on the ridership, the number of trips per passenger was calculated over the study period. that was illustrated in Figure 5. Again, this has revealed that there was no relation between the ridership and the population.

This shall be further studied in details to illustrate the impact by studying the demographic parameters of the population, income and population characteristics on the ridership.

4.2.2. Ridership vs. Number of Lines

Following (Liu, et al., 2017) methodology, bus ridership has been assessed against the network expansion. Due to lack of the number of bus stops in the country over the study period, the number of lines was only considered to understand the relationship between the number of lines and the ridership. As such, Mowasalat has been approached to obtain the number of lines over the study period (2012 – 2016). Table 10 shows the number of bus lines in Qatar and the variation in the numbers between 2012 and 2016.

Table 10: Number of Passengers vs. Number of Lines

Year	Number of Passengers	Number of Lines
2012	10,844,066	38
2013	11,739,717	38
2014	10,606,154	40
2015	10,594,215	40
2016	12,711,621	51

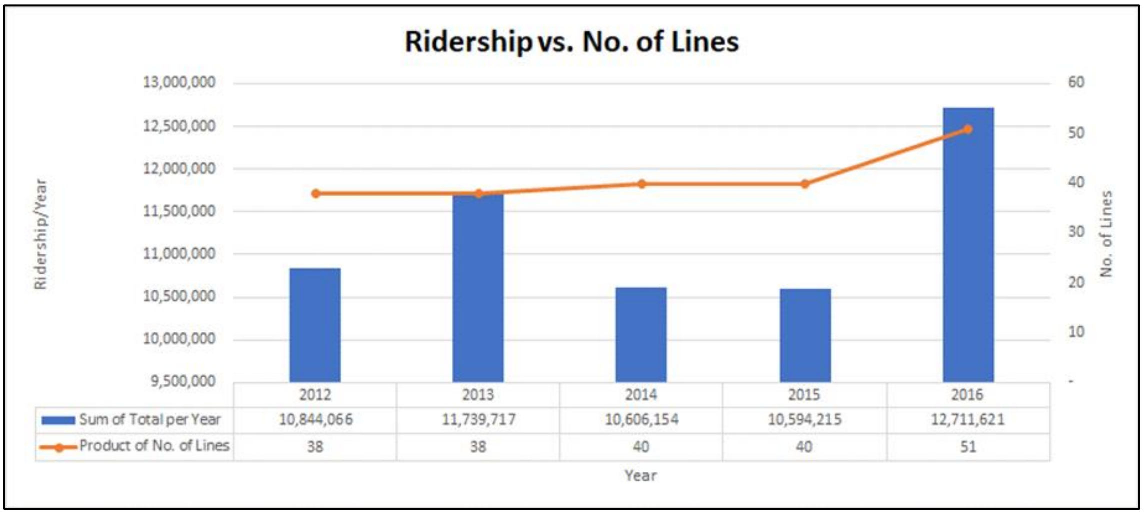


Figure 6: Ridership vs. Network Expansion

Figure 6 has illustrated the relationship between the number of lines (network expansion) and the total ridership per year. The figure did not provide a clear evidence that the number of lines is affecting the ridership. For example, years 2012 – 2013 the number of lines was similar (38 lines) but the ridership was different with around (+ 1 million passengers in 2013), while it had dropped in 2014 and 2015 (– 1 million passengers in both years) while the number of lines was 40 lines in both years. In addition, the ridership had increased by (+ 2 million passengers in 2016) with 51 lines.

This is compatible with Liu et al. (Liu, et al., 2017), where they have concluded that introducing new lines has resulted in diverting the passengers to the new lines and stations. In addition, passenger flow varied with time on the existing lines and stations.

Future studies shall consider the network expansion by considering the added routes and stops each year, and focus on the passengers shift to the new routes and passengers behavior.

4.2.3. Ridership per Weekdays and Weekends

The ridership over the weekdays and weekends was also studied following Yetiskul & Senbil (Yetiskul & Senbil, 2012) who had studied the travel-time variability in the public transit bus system, by developing a model to account for variation caused by the transit system over the operational region.

Table 11 shows trend of ridership over the weekdays and weekends. The table clearly elaborates that the highest ridership was during Friday followed by Thursday.

Table 11: Trend of Ridership over days of the week

Day	Total per Day	Average per Day
Sunday	7,537,495	28,879
Monday	7,390,736	28,317
Tuesday	7,329,711	28,083
Wednesday	7,197,534	27,577
Thursday	8,534,062	32,698
Friday	11,372,175	43,572
Saturday	7,134,060	27,334

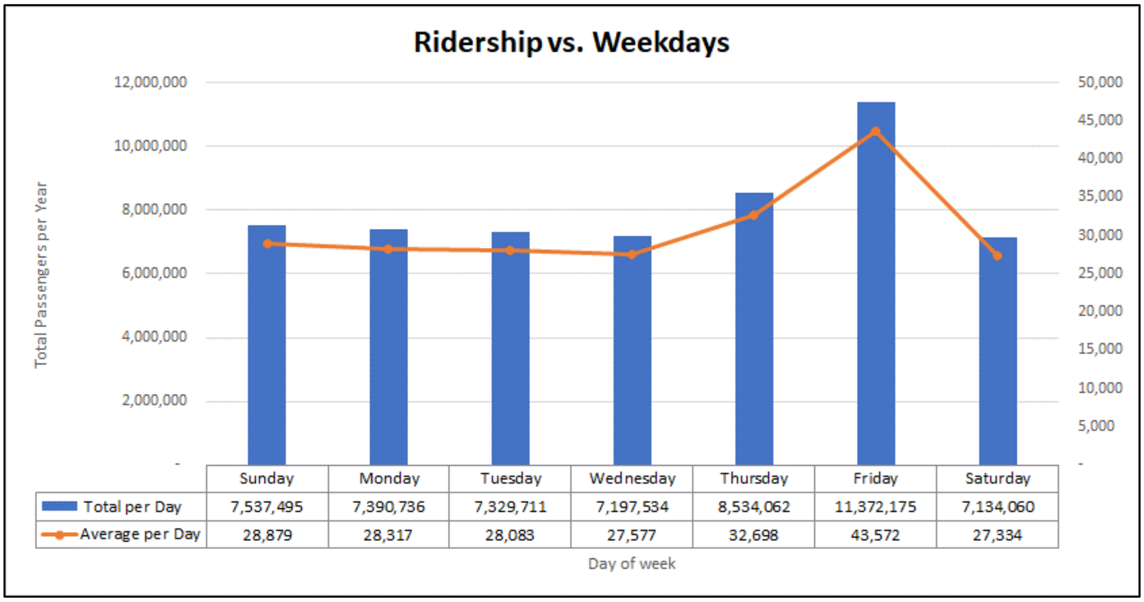
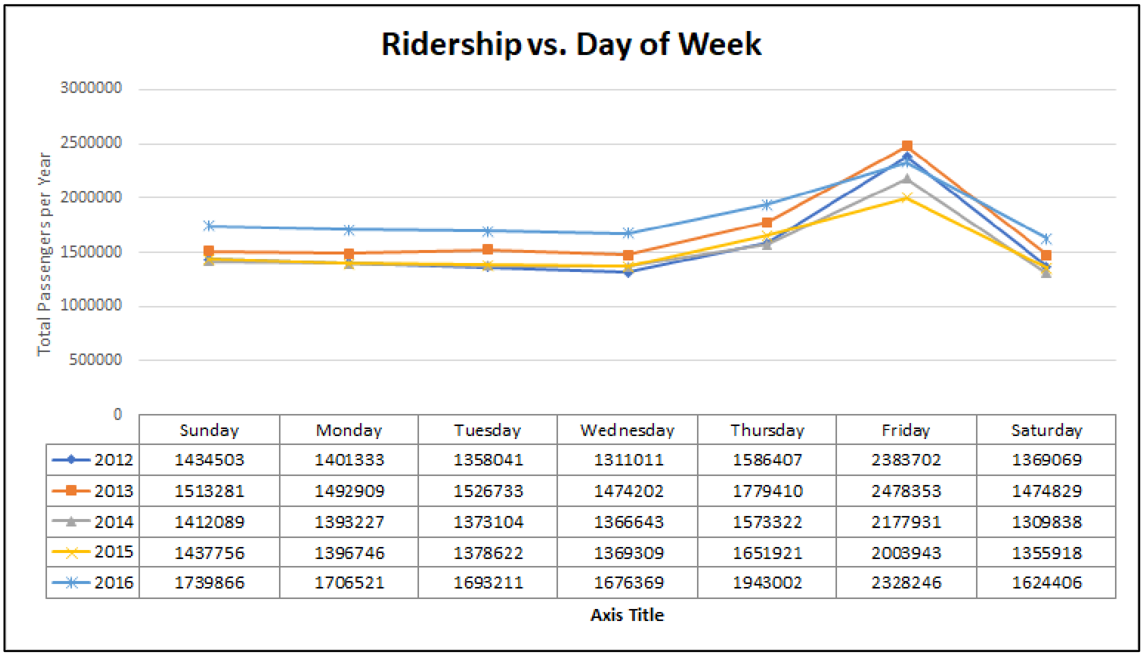


Figure 7: Trend of Ridership over days of the week

The assessment was conducted over the study period (2012 – 2016) to show the ridership trend over the study period. In each year, Friday had the highest ridership with the difference in the total ridership per year but still have the highest. This clarifies that most of the passengers have the common rest days and behavior. Figure 8 shows the trend over the weekdays and weekends for all years.



	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2012	1434503	1401333	1358041	1311011	1586407	2383702	1369069
2013	1513281	1492909	1526733	1474202	1779410	2478353	1474829
2014	1412089	1393227	1373104	1366643	1573322	2177931	1309838
2015	1437756	1396746	1378622	1369309	1651921	2003943	1355918
2016	1739866	1706521	1693211	1676369	1943002	2328246	1624406

Figure 8: Yearly Ridership Trend over days of the week

4.2.4. Weather Impact

The weather impact on the ridership was also assessed in this section following Arana et al. (Arana, et al., 2014), to understand the passengers' behavior during different seasons over the year. As such, the weather data including min, max and average temperature (^{o}C) as well as the precipitation percentage were collected from the Weather Spark website (WeatherSpark, 2017). Before exploring the weather impact, the trend of the ridership over the months shall be presented to understand the average ridership per season. Figure 7 illustrates the trend of ridership (total and average per month).

Table 12: Trend of Ridership per month

Date	Total per Month	Average per Month	Standard Deviation
Jan	4,658,183	30,053	6,640
Feb	4,363,433	30,728	6,802
Mar	4,886,478	31,526	7,246
Apr	4,742,182	31,615	6,862
May	4,902,679	31,630	6,860
Jun	4,520,594	30,137	6,354
Jul	4,495,326	29,002	7,222
Aug	4,618,214	29,795	7,421
Sep	4,541,208	30,275	6,762
Oct	5,005,866	32,296	7,160
Nov	4,854,102	32,361	6,930
Dec	4,907,508	31,661	7,297

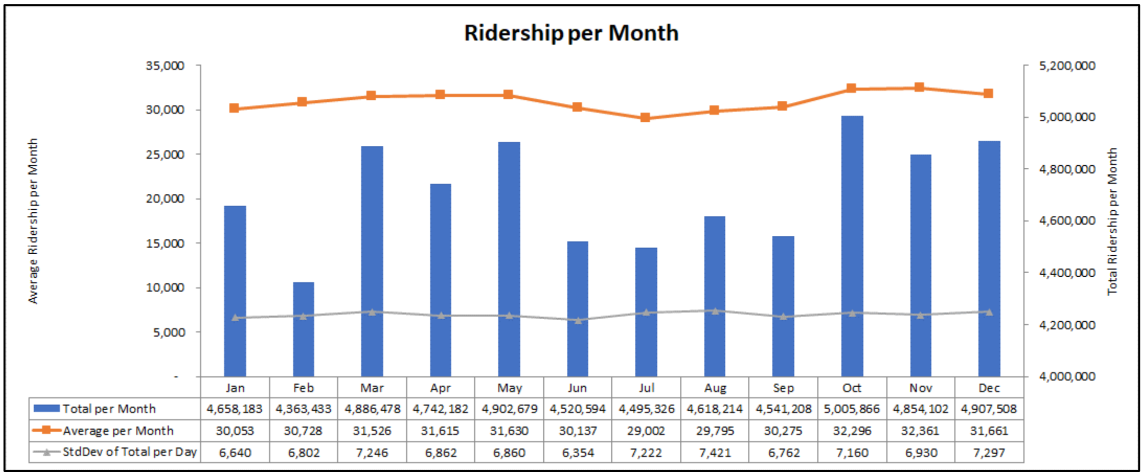


Figure 9: Trend of Ridership over the months

From Figure 9, there is an evident that the ridership varies over the year from month to another. However, the total ridership per month does not provide a good representation of the ridership, for example, February shows the lowest total ridership if compared to other months, which is due to the number of days during the month (28 days). Therefore, the average and the standard deviation have been calculated to provide a better representation of the ridership.

Referring to Figure 9, the average ridership line shows that the summer period especially July have the lowest ridership with an average of (29,002 passengers) and November has the highest with an average of (32,361 passengers). There is a common statement in Qatar that the ridership, walking and any outside activities are minimal during the summer season. As such, the weather data was collected from Qatar Meterorology Department if the Civil Aviation Authority and Weather Spark website (Qatar Meteorology Department, 2017) (WeatherSpark, 2017), and the data was drawn in

Table 13 and Figure 10.

Table 13: Weather Data (Qatar Meteorology Department, 2017)

Months	Temperature			Precipitation (%)
	Min (°C)	Max (°C)	Average (°C)	
Jan	14	22	18	4%
Feb	15	23	19	5%
Mar	18	26.5	22.25	6%
Apr	22.6	32	27.3	3%
May	27.5	38	32.75	0%
Jun	30	41	35.5	0%
Jul	31	42	36.5	0%
Aug	31	41	36	0%
Sep	29	39	34	0%
Oct	25.5	34.5	30	1%
Nov	21	29	25	4%
Dec	16.5	23.5	20	4%

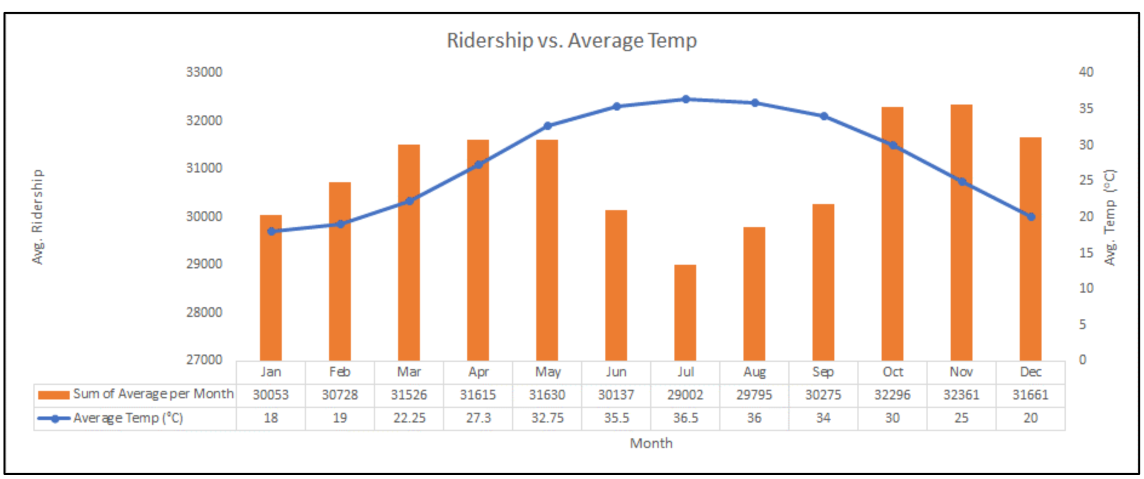


Figure 10: Ridership vs. Average Temperatu

From

Table 13, the highest average ridership was during November and the lowest was during July or the summer season (July, August and September). This would be due to the hot weather during the summer.

This is compatible with the results of research that has been conducted in Doha, where the pedestrian volume is considered the lowest duuring the summer season (Shaaban & Muley, 2016) (Shaaban, et al., 2017). On the other hand, Arana et al. (Arana, et al., 2014) results have shown that when the temperature rises, the number of passengers increased, which is not compatible with the resulted trend shown in Figure 10, instead, in Qatar it has dropped drastically during the summer season.

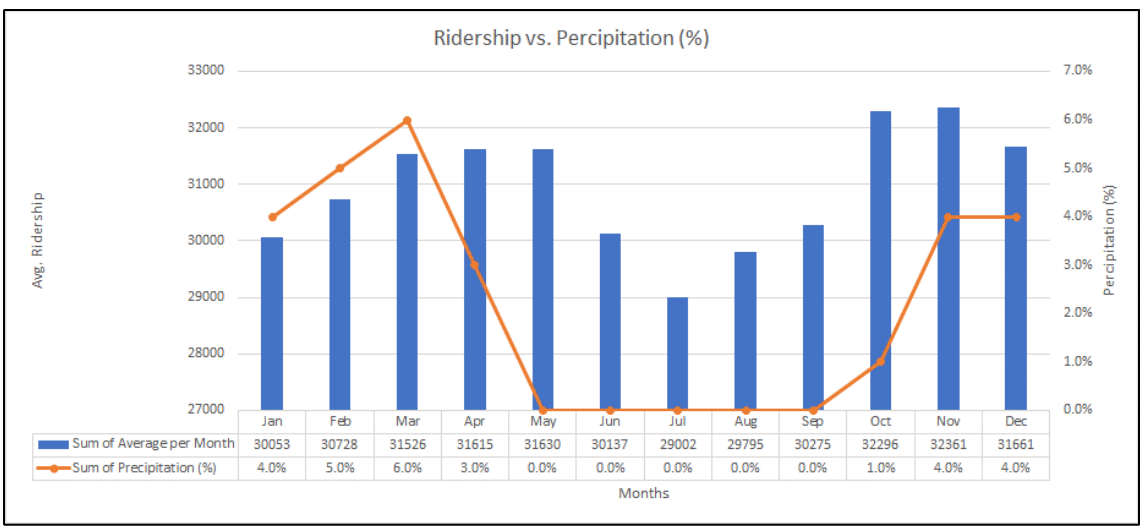


Figure 11: Ridership vs. Precipitation (%)

On the other hand, the ridership has been assessed against the precipitation rates in Qatar. Again, it has shown the similar trend during the summer, and showed a drastic drop in the ridership with the drop in the rainfall. Which again has opposite conclusion if compared to the work done by Arana et al. (Arana, et al., 2014).

CHAPTER 5: MESOSCOPIC LEVEL ASSESSMENT

5.1. Introduction

The trend of boarding and alighting was analyzed to identify the daily, weekdays and weekends trends during the year 2016. In addition, the list of parameters along with the boarding and alighting as shown in Table 4 and Table 5 were extracted to evaluate the correlation between the parameters and conduct the statistical analysis accordingly.

The buses start their journey daily from 04:00 am and ends at 01:00 am, where the last Bus start its journey at 12:00 am. Figure 12 and Figure 13 illustrates the variation of daily boarding and alighting per stop within Greater Doha. The following paragraphs elaborate more on the variation and trend in the boarding and alighting per stop.

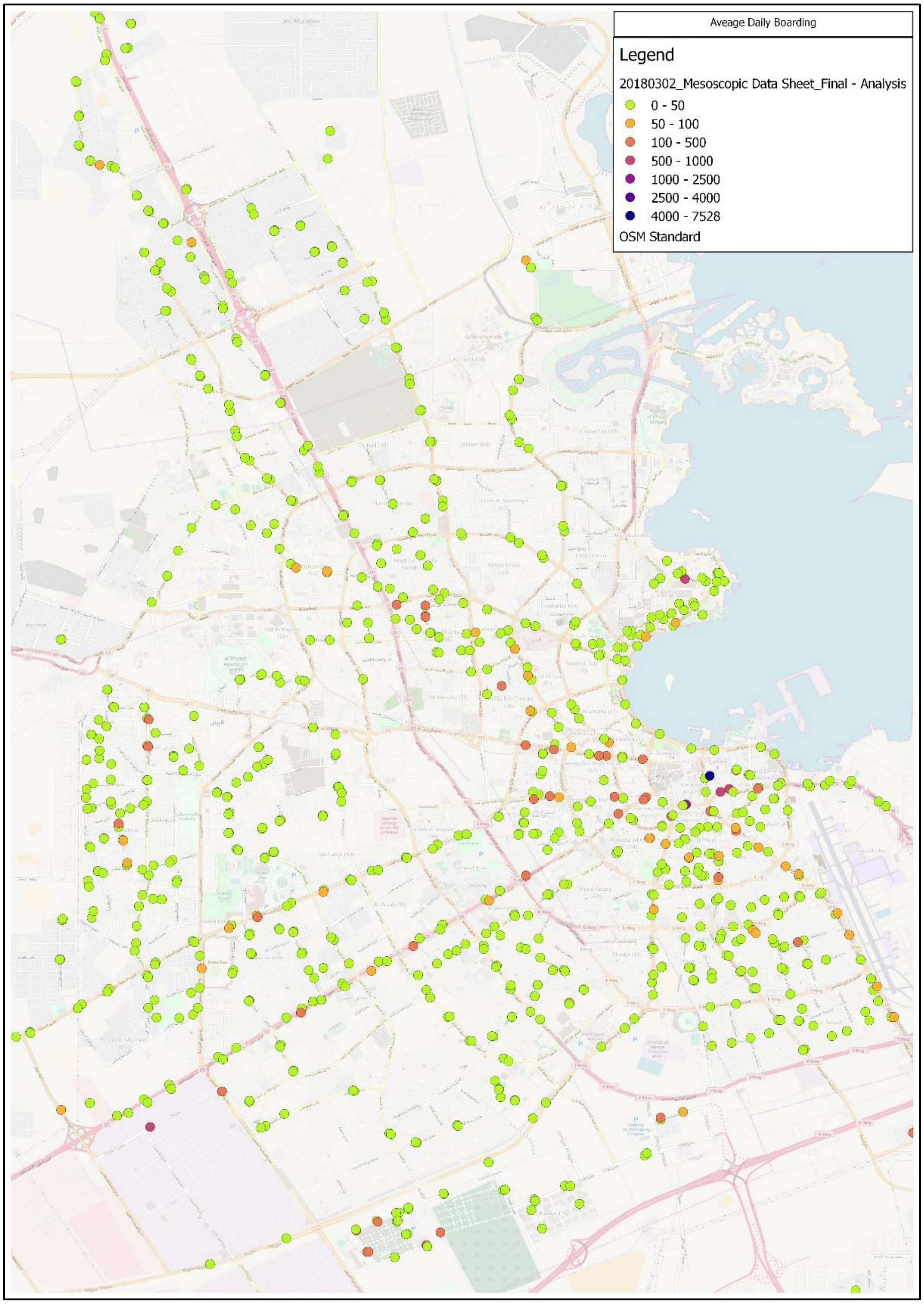


Figure 12: Variation of Daily Boarding per Stop in Greater Doha

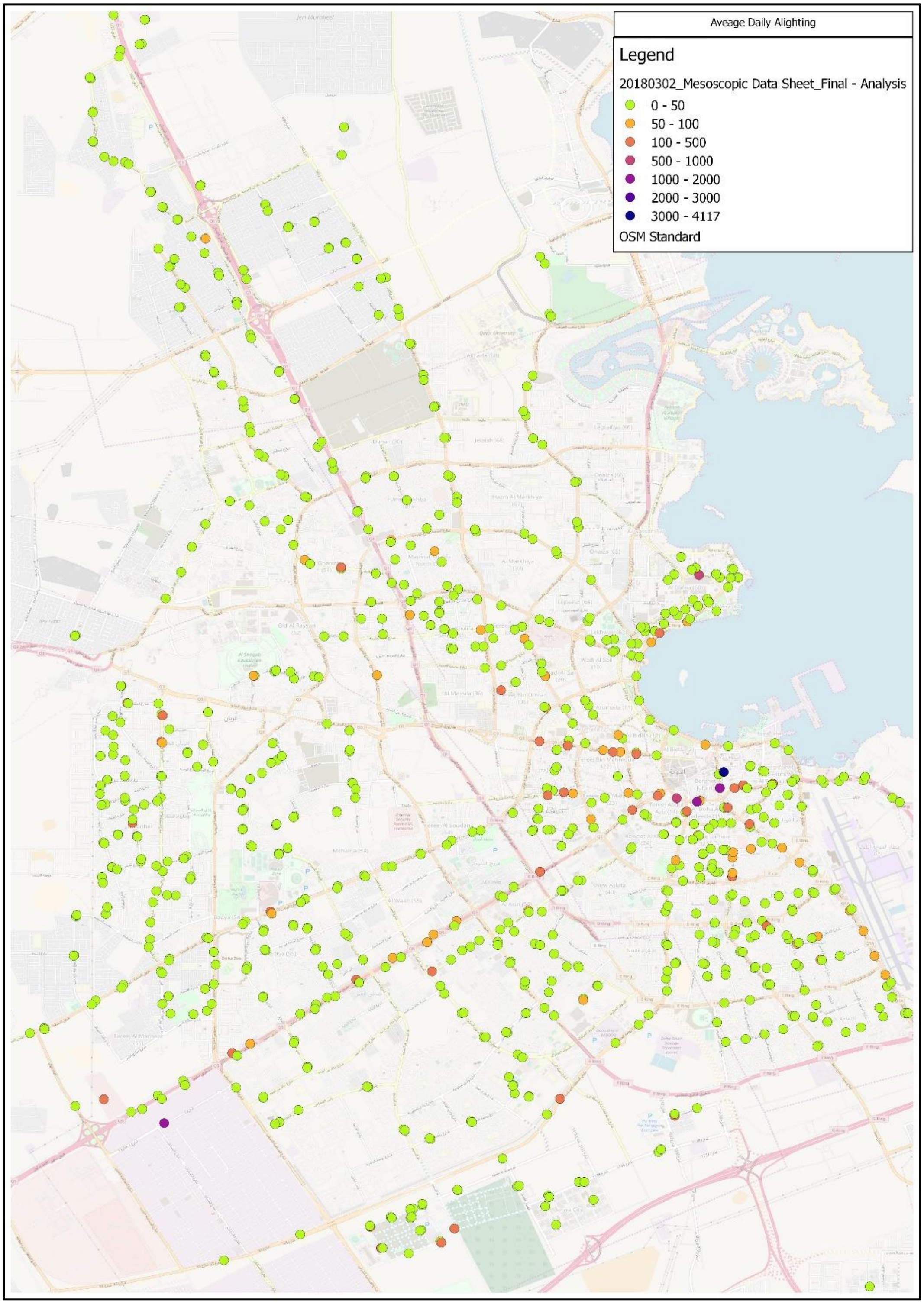


Figure 13: Variation of Daily Alighting per Stop in Greater Doha

The detailed stop level daily boarding/alighting data for the year 2016 has been collected from Mowasalat. Figure 14 and Figure 15 illustrate the trend of the boarding and alighting vs. time of the day per line for the year 2016. Further details related to the stop level are provided in the following sections.

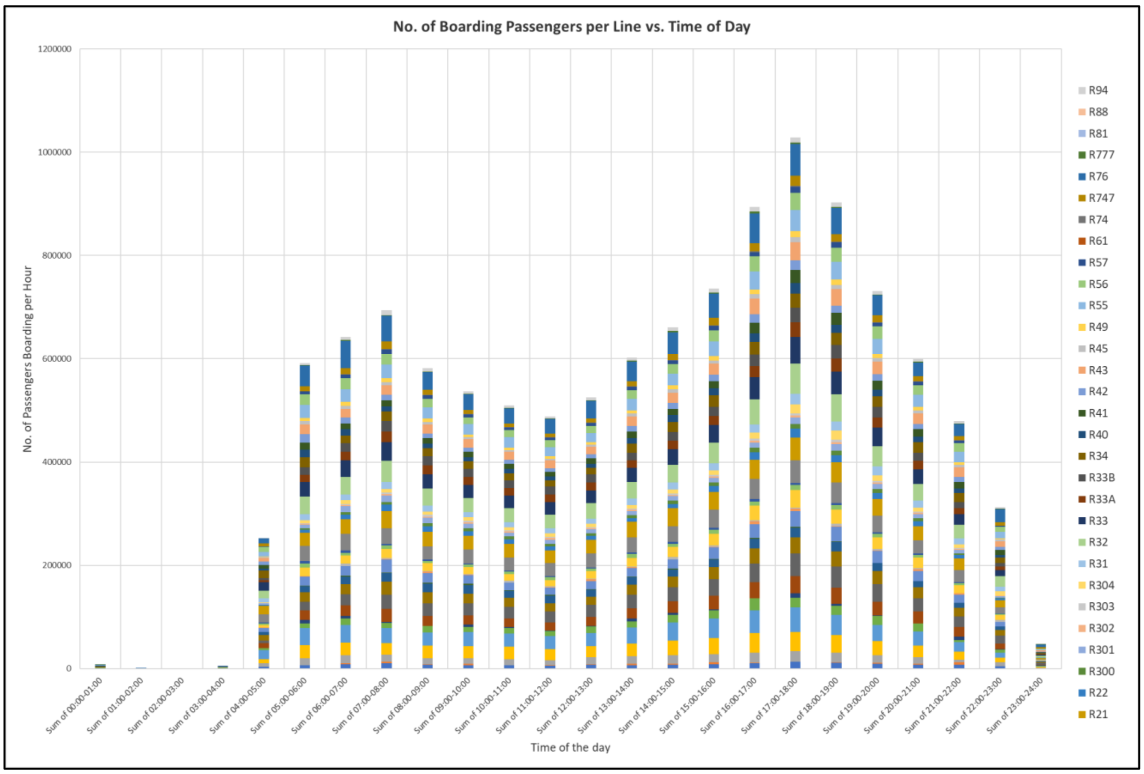


Figure 14: Trend of No of Boarding Passengers per Line per Hour

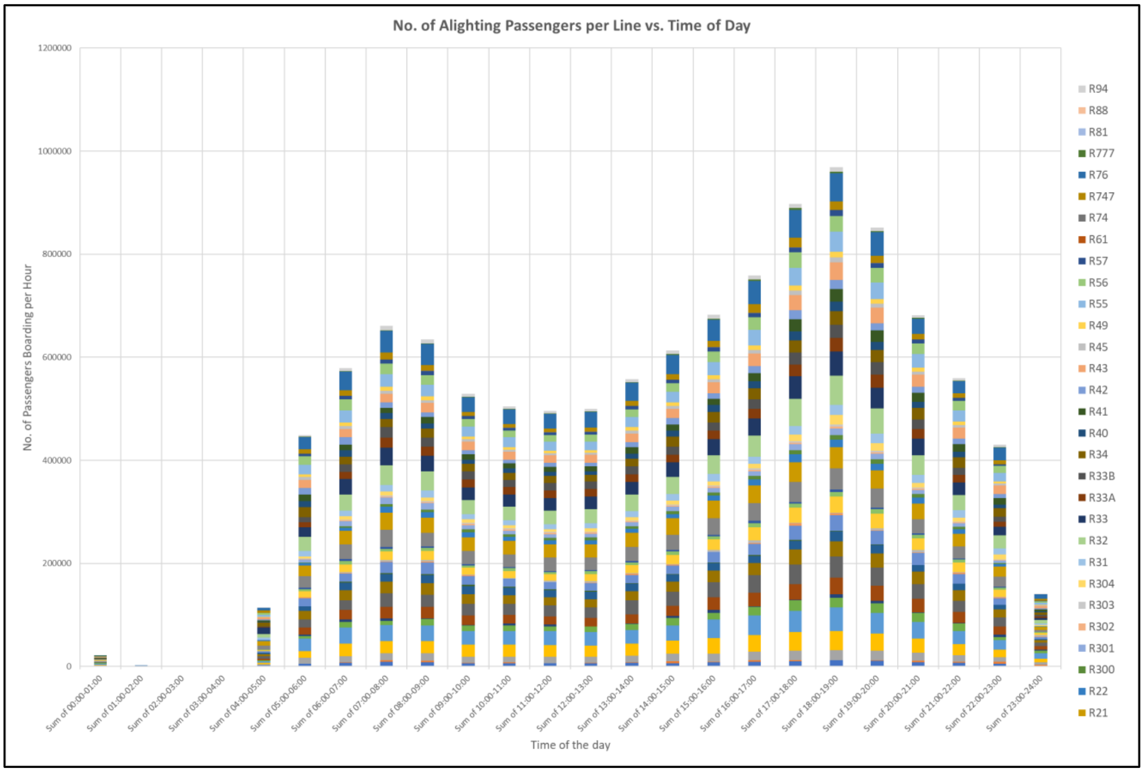


Figure 15: Trend of No of Alighting Passengers per Line per Hour

It is clear from Figure 14 and Figure 15 that the morning peak hour for both boarding and alighting is similar which is from 07:00 – 08:00 am, while the evening peak hour is different where for the boarding, the peak hour is from 05:00 – 06:00 pm and for the alighting is from 06:00 – 07:00 pm.

In addition, the total boarding and alighting on both bus routes and stops in Qatar have been assessed to emphasis on the highest ridership routes and stops and to understand their nature and the relation with the neighborhood. Figure 16 and Figure 17 illustrate the trend of boarding and alighting per line. This assessment revealed to the following:

1. The highest route in terms of both boarding and alighting was route (76) with total boarding of (725,574) passengers and alighting of (663,382) passengers for year (2016) only. Figure 18 shows the extent of Route (76). The route starts from Al Ghanim Station (Stop 600) located in the Doha Down Town passing by the Corniche and the West Bay area. The Corniche Area is considered as a recreational area with tourism activities, while the West Bay area is considered as a business district for the country where most of the government agencies, companies, hotels and leisure activities are located in.

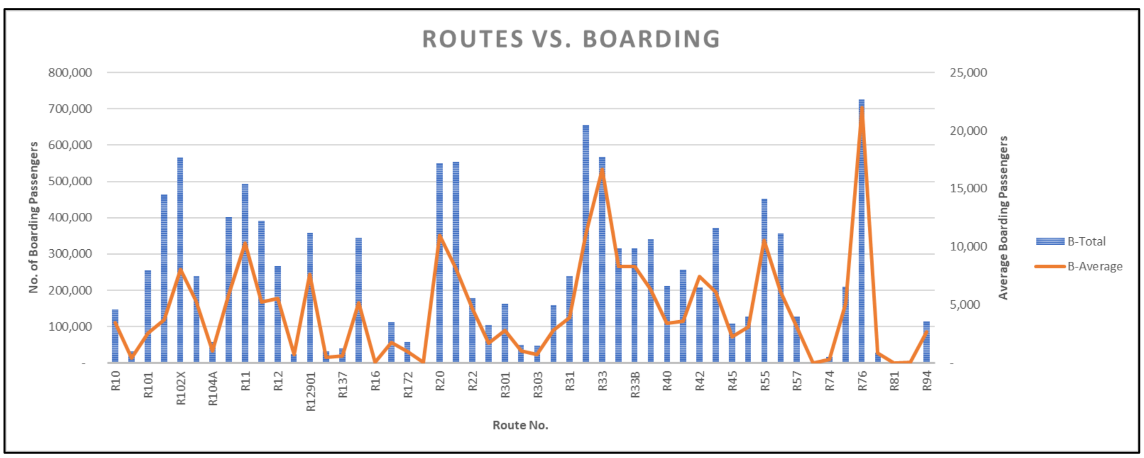


Figure 16: Number of Boarding Passengers per Route (Total & Average)

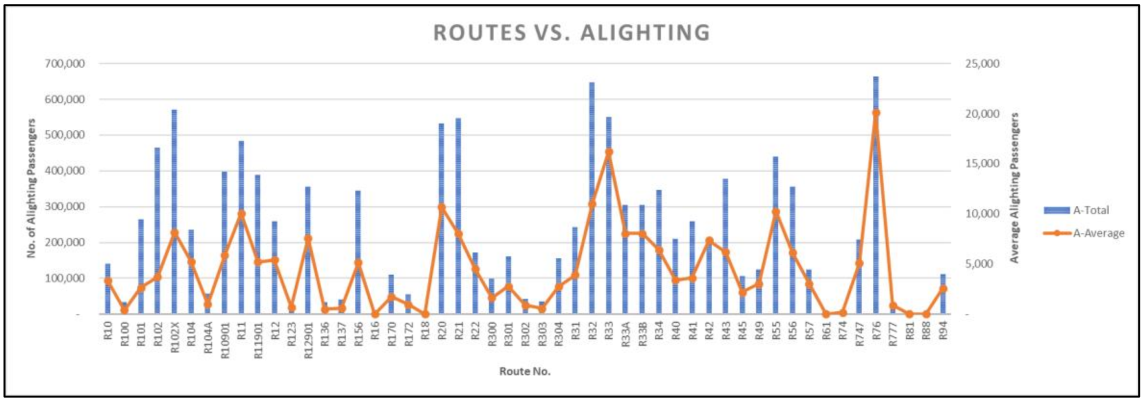


Figure 17: Number of Alighting Passengers per Route (Total & Average)

Figure 18: Extent of Route 76

2. The highest stop in terms of boarding and alighting was stop (600). The total daily boarding recorded in 2016 only was (2,830,689) passengers while the total daily alighting was (1,464,317) passengers. The reason for the high

boarding and alighting was due to the fact that most of the routes (38 routes) are either starting, passing or terminating at this station. Figure 19 illustrates the location of Al Ghanim Station and the routes passing through.

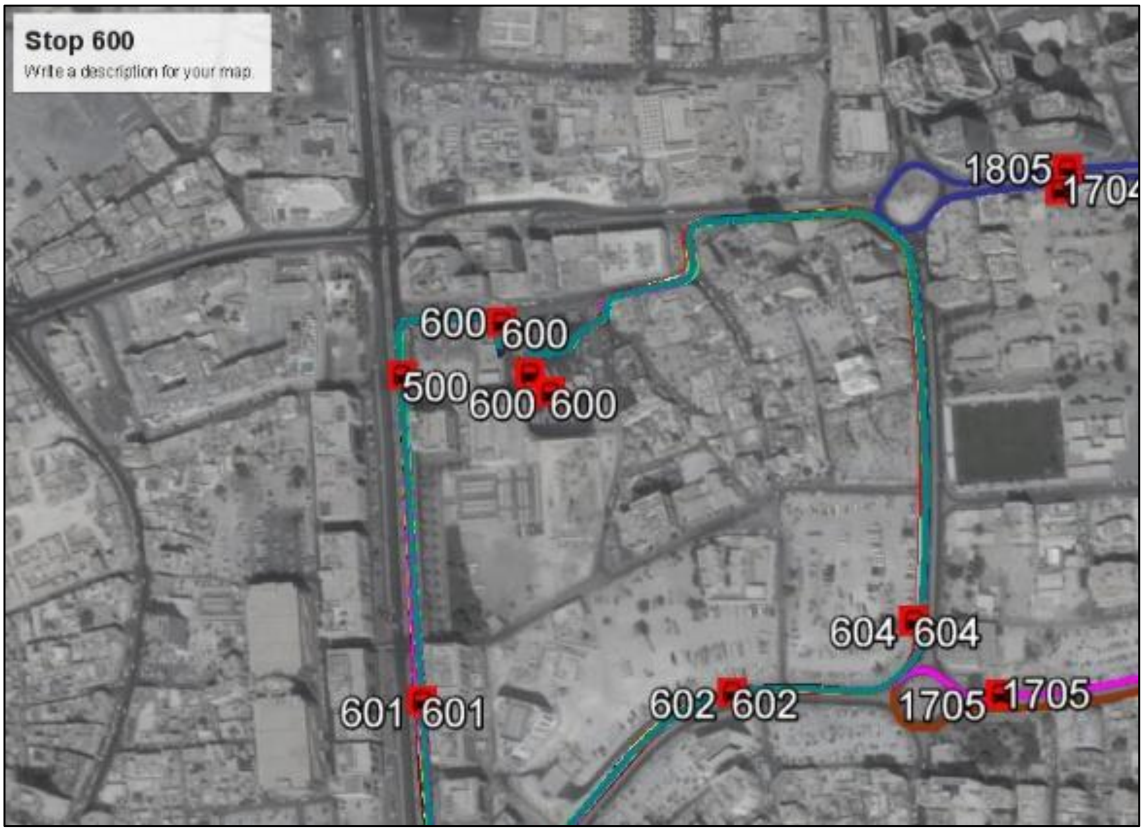


Figure 19: Stop 600 – Al Ghanim Station

5.2. Bus Ridership

5.2.1. Boarding and Alighting vs. Time of the Day

The average hourly boarding passengers for the year 2016 has been calculated and the top 10 stops as far as the number of boarding passengers are presented in Table 14.

Table 14: Highest 10 Stops in Average Hourly Boarding and Alighting

Stop ID	Average Hourly Boarding	Average Hourly Alighting	Stop ID
600	117,945.38	61,013.21	600
408	26,988.50	29,445.04	601
604	14,201.75	18,134.96	1505
602	13,359.75	13,648.79	1409
1800	10,151.88	12,197.13	1800
11	9,684.54	8,142.04	11
1508	5,634.33	6,003.58	5542
1312	5,318.79	5,070.29	1413
3821	4,977.96	4,605.96	5000
1413	4,025.75	4,401.50	56661

As shown in Table 14 , stop (600) had again the highest average hourly boarding and alighting in 2016. The highest stops are distributed over the country and not located in one area, for example, Stop (11) is located in the West Bay Area at the City Center Doha Mall, while stop (1800) is located in the Industrial Area at Street (1). Stop (3821) is located along Al Rayyan Road opposite to Hamad General Hospital and near the Lulu Hypermarket, where both land uses are considered attractive to the type of passengers of the bus system in Qatar. Figure 23 shows the locations of those stops.

Stops (600, 601, 602 and 604) are located close to each other within the downtown area and close to the Al Ghanim Station (600), while Stops (408, 1505, 1409 and 1508) are located farther, for example, stops 408, 1505 and 1409 are located at the A-Ring Road in both directions and stop Number 1508 is located along Al Matar Street but still close to Al Ghanim Station as shown in Figure 20 .

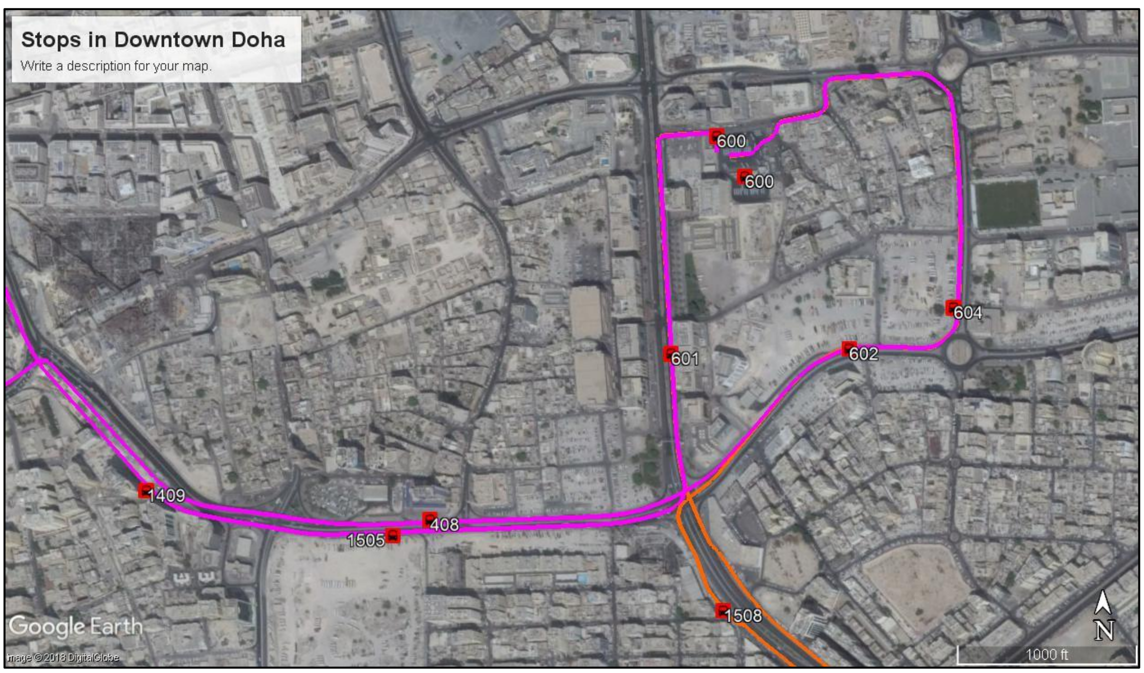


Figure 20: Stops within Down Town Doha

5.2.2. Daily, Weekday, and Weekend Boarding and Alighting

Previously, Mowasalat had different timetables for the weekdays (Saturday – Thursday) and weekends (Friday). This has been changed since May 2017 and now Friday and Saturday are considered weekends and have their different timetables. However, since the data utilized in the study is for the year 2016, the corresponding timetable at the study period is considered and Friday will be the only weekend day.

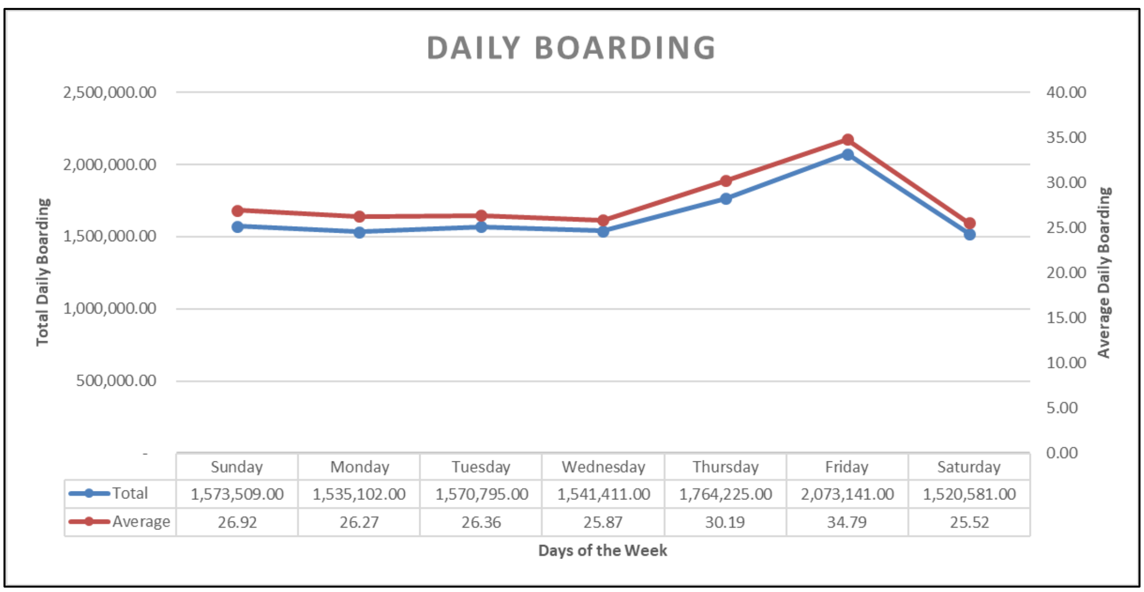


Figure 21: Trend of Boarding over days of the week

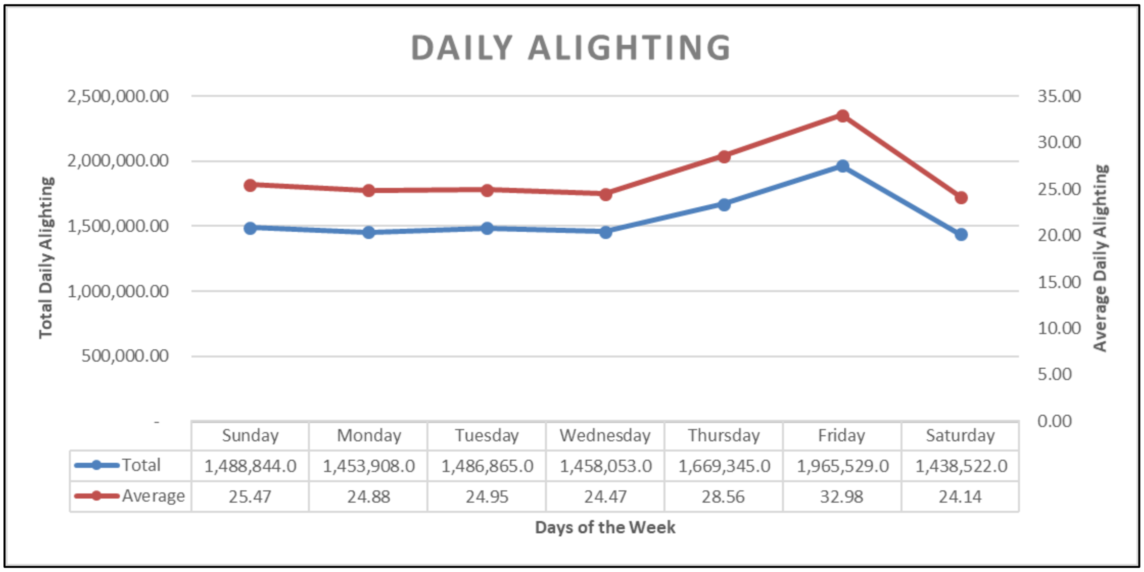


Figure 22: Trend of Alighting over days of the week

Figure 21 and Figure 22 show the trend of both boarding and alighting passengers over days of the week. Those figures clearly show that the weekend (Friday) has the highest ridership among the entire week, followed by Thursday. However, for the rest of the week, the ridership is homogeneous from Saturday to Wednesday.

To highlight the stop level ridership, the daily, weekday and weekend boarding and alighting data have been compiled and the highest 10 stops in terms of boarding and alighting are presented in Table 15, Table 16 and Table 17.

Table 15: Highest 10 Stops in Daily Boarding and Alighting

Stop ID	Total Daily Boarding	Average Daily Boarding	Average Daily Alighting	Total Daily Alighting	Stop ID
600	2,717,612.00	7,528.01	4,116.96	1,486,222.00	600
408	614,847.00	1,703.18	1,894.98	684,086.00	601
604	324,386.00	898.58	1,177.93	425,231.00	1505
602	306,311.00	848.51	1,048.61	378,548.00	1800
11	269,607.00	746.83	884.61	319,344.00	1409
1800	244,741.00	677.95	689.80	249,018.00	11
1508	131,241.00	363.55	343.75	124,094.00	1413
55641	117,062.00	324.27	312.23	112,716.00	5000
1312	116,390.00	322.41	287.78	103,890.00	56661
3821	115,968.00	321.24	274.61	99,133.00	5428

Table 16: Highest 10 Stops in Weekday Boarding and Alighting

Stop ID	Total Weekday Boarding	Average Weekday Boarding	Average Weekday Alighting	Total Weekday Alighting	Stop ID
600	2,081,518.00	6,736.30	3,803.03	1,175,137.00	600
408	530,691.00	1,717.45	1,788.65	552,693.00	601
604	277,730.00	898.80	1,169.67	361,427.00	1505
602	271,989.00	880.22	956.84	295,664.00	1800
11	227,351.00	735.76	849.25	262,419.00	1409
1800	179,910.00	582.23	666.35	205,903.00	11
1508	114,876.00	371.77	357.66	110,517.00	1413

Stop ID	Total Weekday Boarding	Average Weekday Boarding	Average Weekday Alighting	Total Weekday Alighting	Stop ID
55641	91,439.00	295.92	269.58	83,299.00	5428
1312	101,685.00	329.08	268.83	83,068.00	5000
3821	105,463.00	341.30	267.59	82,685.00	1609

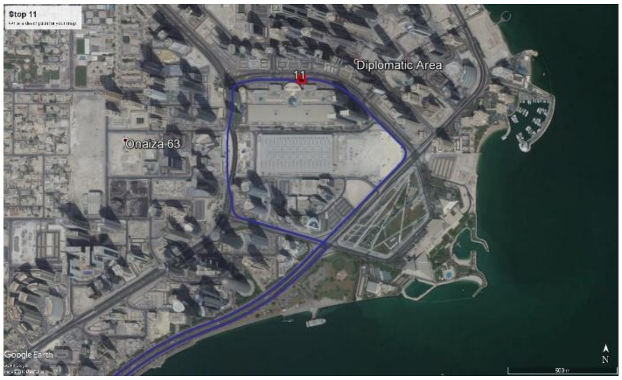
Table 17: Highest 10 Stops in Weekend Boarding and Alighting

Stop ID.	Total Weekend Boarding	Average Weekend Boarding	Average Weekend Alighting	Total Weekend Alighting	Stop ID.
600	636,094.00	12,232.58	5,982.40	311,085.00	600
408	84,156.00	1,618.38	2,526.79	131,393.00	601
1800	64,831.00	1,246.75	1,593.92	82,884.00	1800
604	46,656.00	897.23	1,227.00	63,804.00	1505
11	42,256.00	812.62	1,094.71	56,925.00	1409
602	34,322.00	660.04	829.13	43,115.00	11
55641	25,623.00	492.75	570.15	29,648.00	5000
5698	25,520.00	490.77	532.98	27,715.00	5696
8893	18,774.00	361.04	497.08	25,848.00	6000
55783	16,924.00	325.46	437.17	22,733.00	56661

Comparing the results of Table 14 (Average Hourly), Table 15 (Daily), Table 16 (Weekday) and Table 17 (Weekend), the following can be concluded:

1. Stops 600, 11 and 1800 are common in all statistics with the highest boarding and alighting passengers in all periods. The rest of stops varies based on various elements, like location, period, Number of lines, and type of lines.
2. Most of the highest stops in terms of daily, weekday and weekend boarding and alighting are located in the industrial area and the surrounding zones, like, Stops Number (1800, 5000, 6000, 56661, 5542, 55641 and 55783) (Figure 23).
3. From on-site observations, most of the bus passengers during weekends are labors and people with low-income, who have Friday as a common weekend. Table 17 lists 10 stops with highest boarding and alighting during weekends. Seven of these stops are common with the stops with highest daily, weekday and even the hourly boarding, however, Stops Number (5696, 5698, 6000, 8893 and 55783) are shown in the list with the highest boarding during weekends. Stops Number 5696 and 5698 (Figure 23) are located opposite to Masaken Mesaimeer Development and close to the religious complex. Masaken Mesaimeer is a housing development developed by Barwa Real-estate Company to provide a high-quality affordable community housing (BARWA, 2018). Stop Number (6000) (Figure 23) is located close to Karwa Accommodation and Headquarter. Stop Number 8893 (Figure 23) is located along Al Khor Coastal Road toward Doha and located in close proximity to farms that accommodate labor camps. The last one, Stop Number 55783

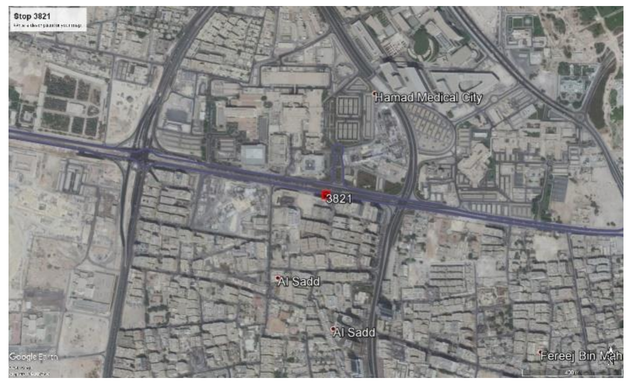
(Figure 23) is located in the Industrial Area at Street 52 and surrounded by many labor camps.



Stop Number 11

Stops Number 1312 and 1413

Stop Number 1800



Stop No, 3821

Stop Number 5000, 6000 and 56661

Stop Number 5542

Stop Number 1609

Stop Number 5428

Stop Number 55641

Stop No 5696 and 5698

Stop Number 8893

Stop Number 55783

Figure 23: Stops with Highest Boarding and Alighting

5.3. Infrastructure Parameters

The Infrastructure Parameters of the country for the corresponding year 2016 have been collected and utilized. The infrastructure data within (500 m) stop's catchment area has been compiled to assess their influence on the ridership. The stops with highest and lowest values of infrastructure parameters are listed in Table 18 and Table 19 . For the lowest values, all catchment areas with (0) values have been ignored, as it found many of catchment areas have no land use parameters values or in 2016, due to many reasons, either the stops are located in undeveloped areas, or due to the outdated land use layers as clarified earlier.

It is clear from the table and the figure that any stop with high value in any of the infrastructure parameters does not mean that the rest are the highest.

Table 18: Stops with Highest Corresponding Infrastructure Parameters

Infrastructure Element	Stop ID with Highest Value	Corresponding Value
Road Length (m)	3416	25,708.89
Footpath Area (m^2)	5430	114,237.16
Bile Lanes Area (m^2)	9986	21,538.63
Parking Area (m^2)	55660	125,885.19

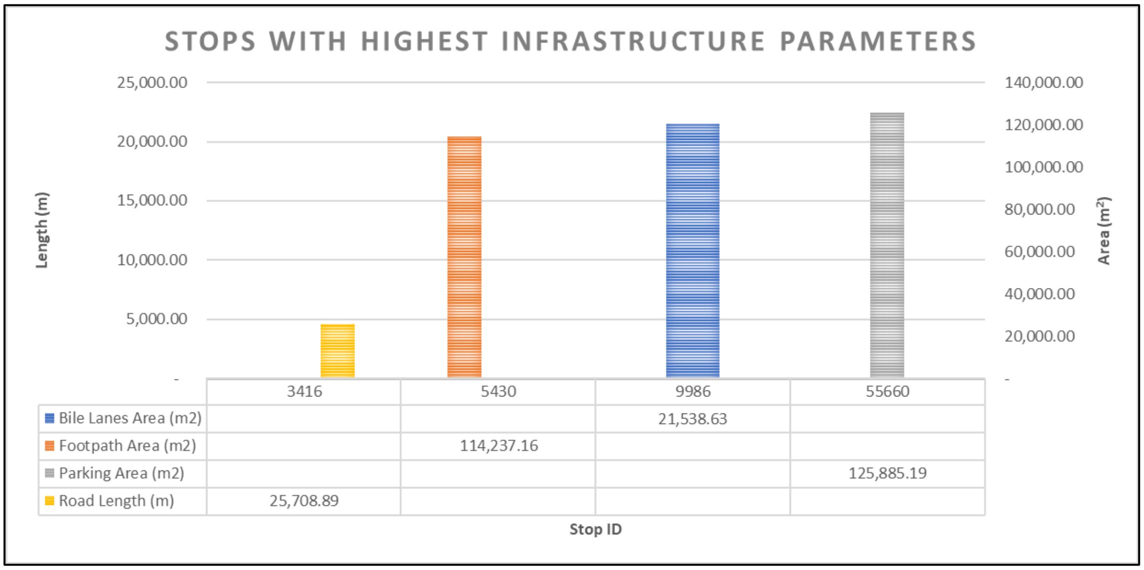


Figure 24: Stop ID with Highest Corresponding Infrastructure Parameters

Table 19: Stops with Lowest Corresponding Infrastructure Parameters

Infrastructure Element	Stop ID with Lowest Value	Corresponding Value
Road Length (m)	5542	130.34
Footpath Area (m^2)	9736	3
Bile Lanes Area (m^2)	9744	0.3
Parking Area (m^2)	95550	20

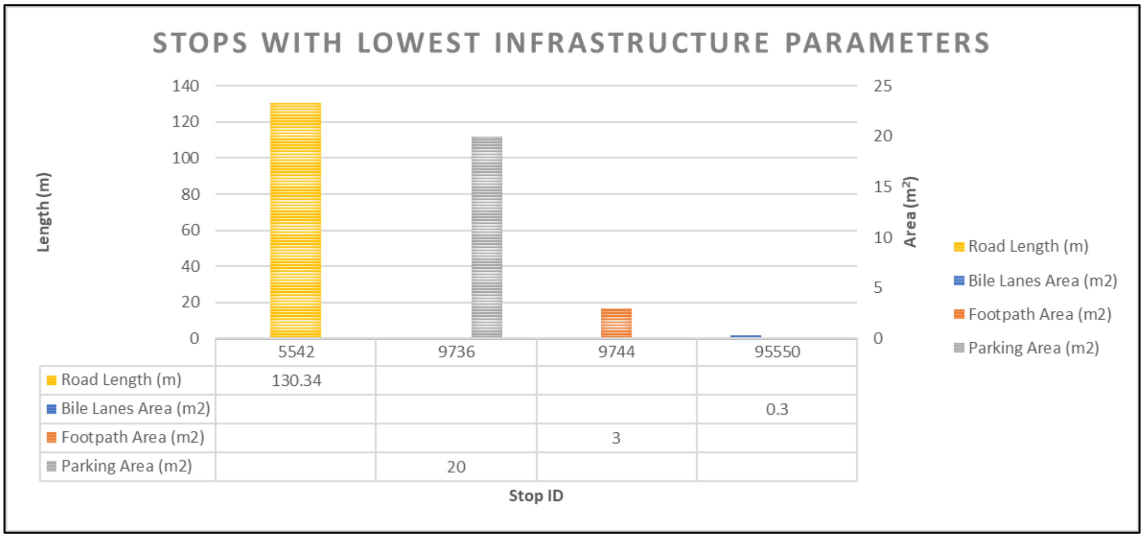


Figure 25: Stop ID with Lowest Corresponding Infrastructure Parameters

However, to understand the relationship between the ridership and the infrastructure parameters, the stops with highest boarding and alighting has been listed along with the corresponding value of infrastructure parameters. Figure 26 and Figure 27 show the variation in the boarding and alighting against the selected infrastructure parameters. It has been divided into two figures due to the difference in the units between the road length (m) and the others (areas m^2).

From Figure 24 and Figure 25, it is obvious that the boarding and alighting are not influenced greatly by the infrastructure parameters, however, the analysis will provide more explanation on this matter.

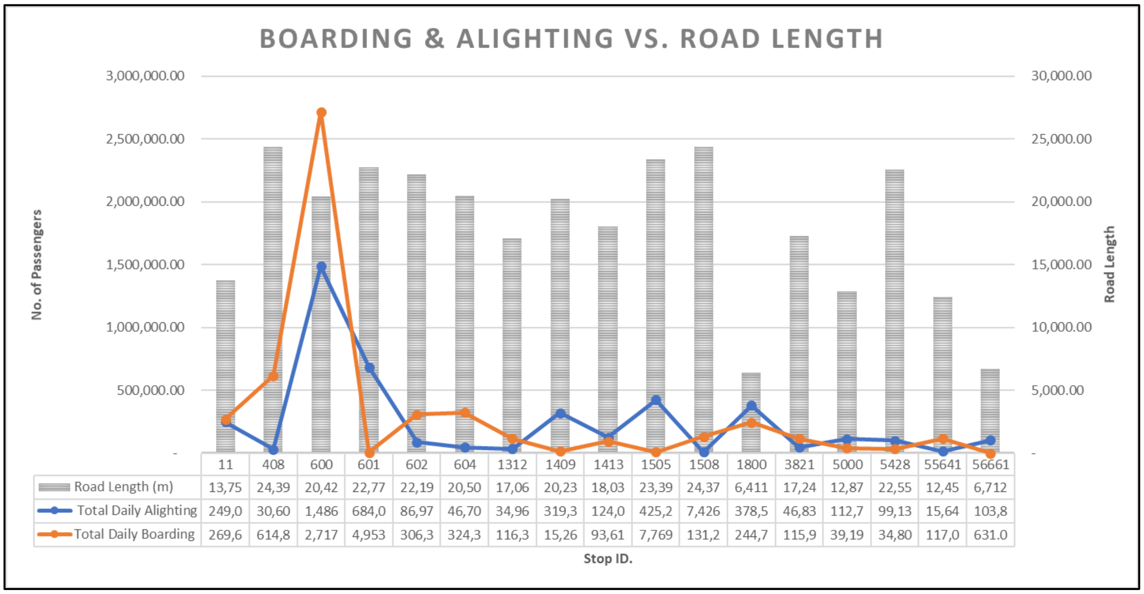


Figure 26: Boarding and Alighting vs. Road Length

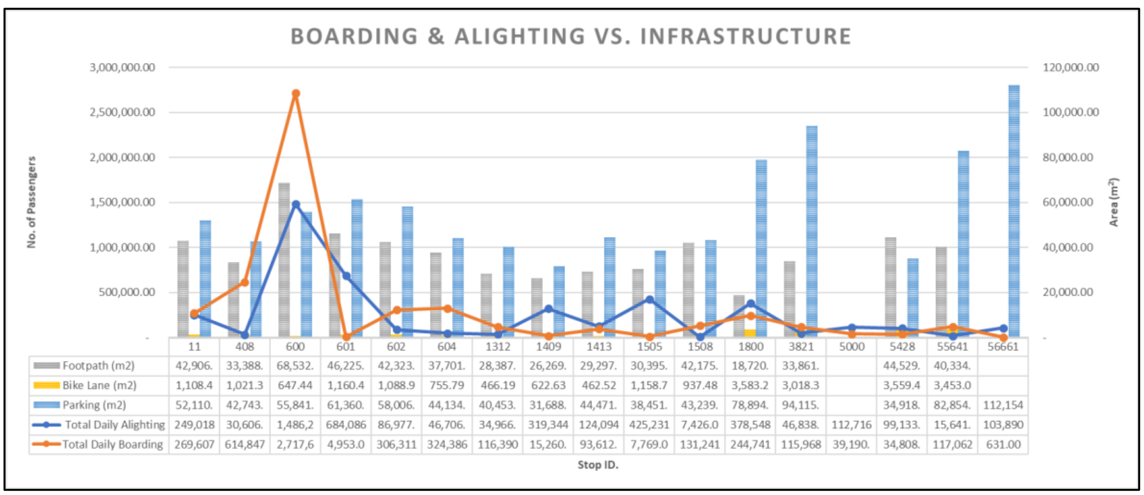


Figure 27: Boarding and Alighting vs. Footpath, Bike Lanes and Parking Areas

5.4. Land Use Parameters

In terms of land use parameters, the population structure of the country for the corresponding year 2016 have been utilized. The population data within (500 m) stop's catchment area have been compiled to assess their influence on the ridership.

The highest and lowest values of land use parameters have been listed in Table 20 and Table 21 respectively. For the lowest values, all catchment areas with zero (0) values have been ignored, as it found many of catchment areas have no land use parameters values or in 2016, due to many reasons, either the stops are located in undeveloped areas, or due to the outdated land use layers as clarified earlier in Chapter 3.

Similar to the relation between the ridership and the infrastructure elements, the stops with highest boarding and alighting have been listed along with the corresponding value of land use parameters including the population and Number of places. Figure 30 and Figure 31 illustrate the variation in the boarding and alighting along with the Number of places and the population groups.

It can be concluded from both figures that there is some influence from those parameters on the ridership, however, to identify which of them has the highest influence, the statistical analysis will be conducted to provide more details.

Table 20: Stops with Highest Corresponding Land Use Parameters

Population Group	Stop ID with Highest Value	Corresponding Value
Employees	4248	68,278
Employer Business	4248	13,171
Personal Business	3721	49,397
Leisure	23	37,128
Number of Restaurants	3956	25
Restaurants Commuters	11	17,690
Shopping Places	600	38
Shopping Commuters	600	105,525
Number of Mosques	2709	12
Number of Schools	5222	7
Number of School Students	5627	6,276
Number of University Students	5228	1,844
Number of Residents	17	32,554

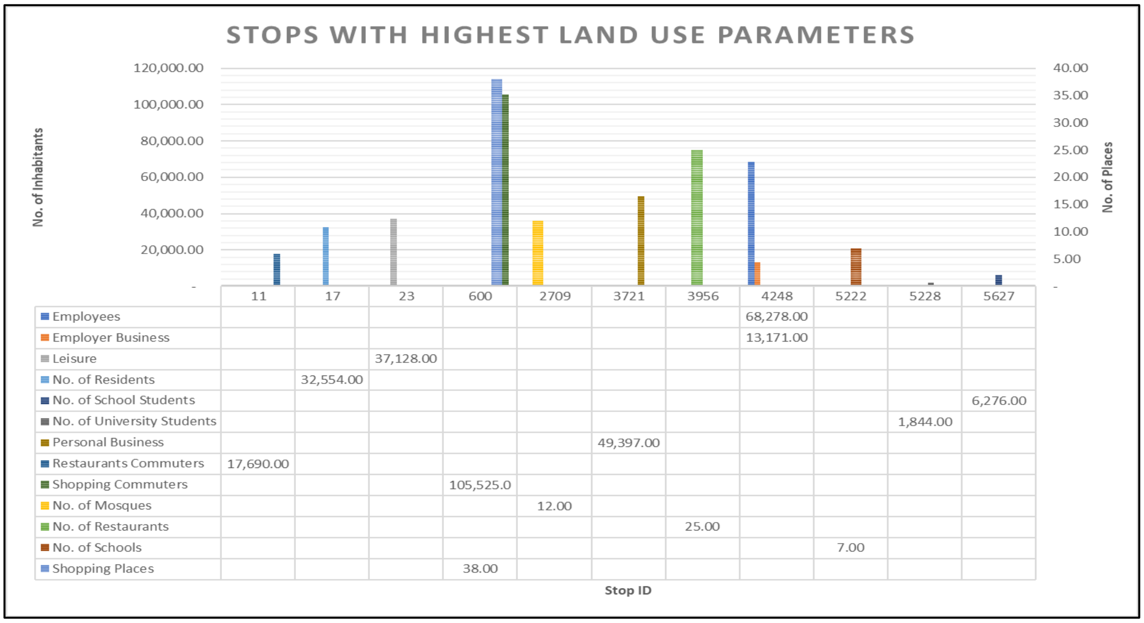


Figure 28: Stops with Highest Corresponding Land Use Parameters

Table 21: Stops with Lowest Corresponding Land Use Parameters

Population Group	Stop ID with Lowest Value	Corresponding Value
Employees	7017	26.45
Employer Business	7017	2.39
Personal Business	5317	9.72
Leisure	9470	0.36
Number of Restaurants	55618	1
Restaurants Commuters	4465	1
Shopping Places	7017	1
Shopping Commuters	7016	20.52
Number of Mosques	7013	1
Number of Schools	2116	1

Population Group	Stop ID with Lowest Value	Corresponding Value
Number of School Students	9470	1
Number of University Students	9949	1
Number of Residents	9470	164

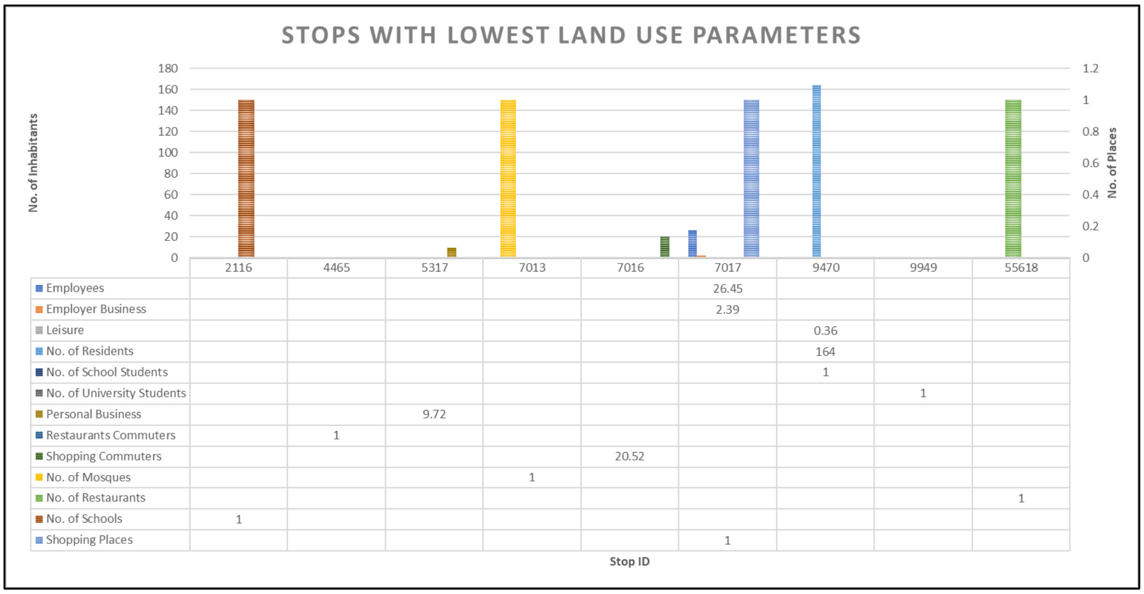


Figure 29: Stops with Lowest Corresponding Land Use Parameters

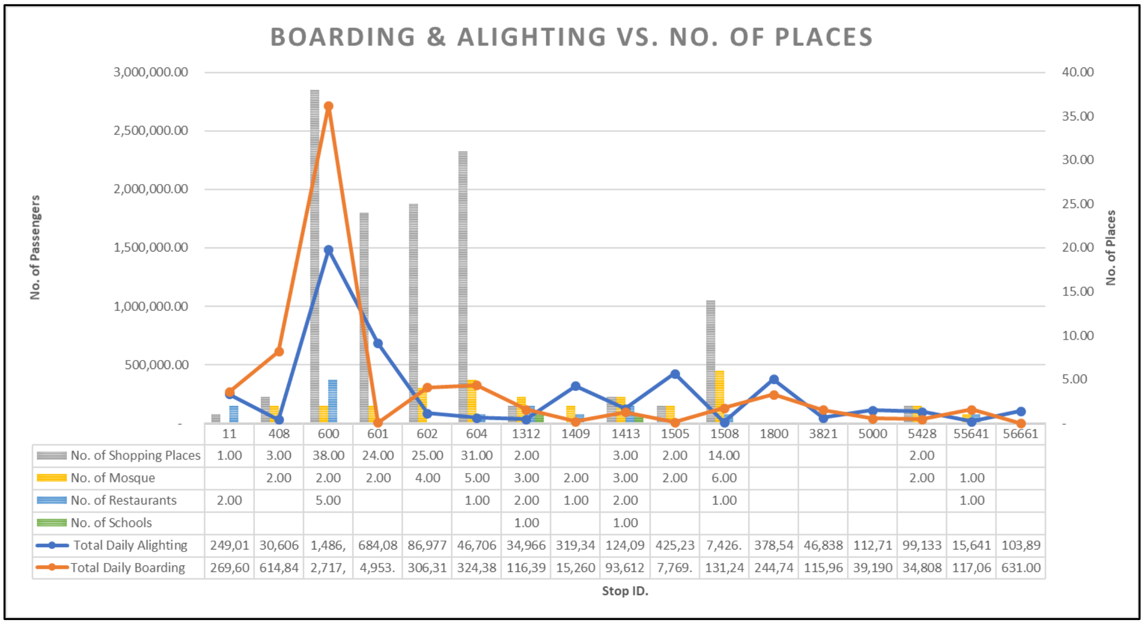


Figure 30: Boarding and Alighting vs. Number of Places

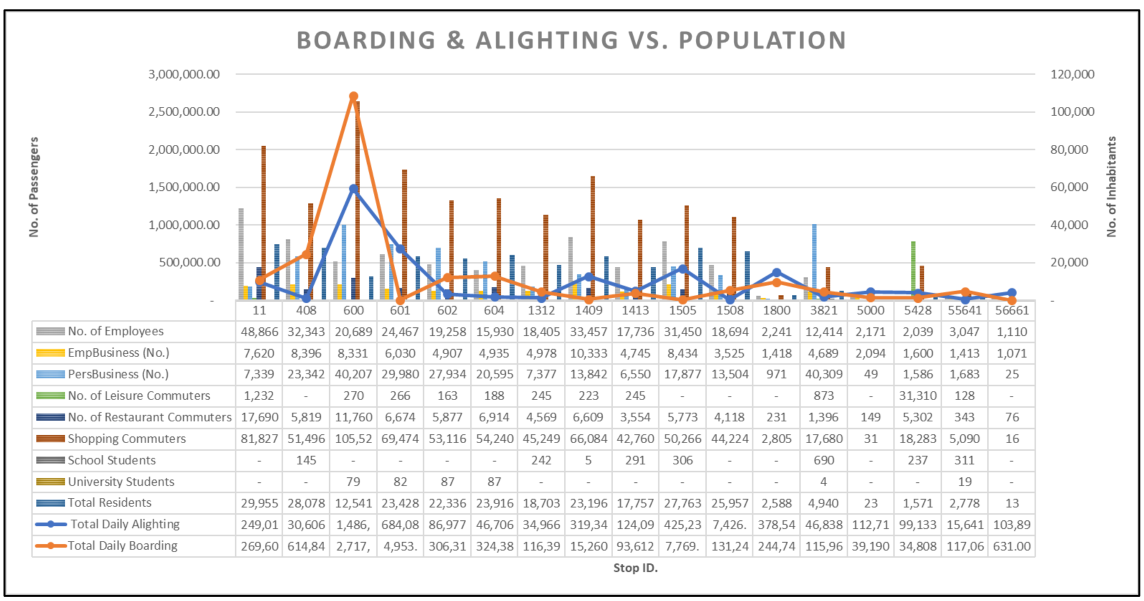


Figure 31: Boarding and Alighting vs. Population

5.5. Regression Analysis

Lastly, multiple regression models were developed, with a prediction goal, to estimate boarding and alighting on different levels based on the bus infrastructure, population, and planning-related attributes. Multiple Linear Regression (MLR) analysis was chosen as it is a robust technique that can model the effect of continuous and categorical variables. The mathematical formulation of MLR model and various measures were presented earlier in Chapter 3. The analysis was conducted using a confidence interval of 95%.

Forward, backward, and stepwise selection methodologies were assessed. The stepwise selection procedure explained the data set better. The stepwise regression model development procedure first considered all the variables to see if their significance has been reduced below the specified tolerance level. The variables were eliminated one at a time starting with the one that had the lowest correlation with the dependent variable. Elimination continued until only statistically significant variables were left in the model. The coefficients and t-statistic for the initial and best models developed by using different input variables and selected using selection criteria are shown in Table 22 – Table 25.

Table 22: Results of Multiple Linear Regression – (Dependent Variable: Average Hourly Boarding and Alighting)

Dependent Variable: Average Hourly Boarding							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-153.084	186.289		-0.822	0.411	-518.753	212.586
Number of Shopping Places	273.408	38.208	0.266	7.156	0	198.41	348.407
Personal Business (Number)	0.101	0.026	0.141	3.878	0	0.05	0.153
Shopping Commuters	0.121	0.019	0.38	6.243	0	0.083	0.159
Total Residents	-0.147	0.03	-0.216	-4.89	0	-0.206	-0.088
Number of Restaurant Commuters	-0.232	0.093	-0.132	-2.49	0.013	-0.415	-0.049
R^2	0.210						
Adj. R^2	0.205						

Dependent Variable: Average Hourly Alighting							
	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	420.533	171.743		2.449	0.015	83.415	757.65
Shopping Commuters	0.101	0.012	0.512	8.714	0	0.078	0.124
Number of Shopping Places	165.667	23.221	0.266	7.134	0	120.086	211.248
Total Residents	-0.062	0.02	-0.153	-3.144	0.002	-0.101	-0.023
Personal Business (Number)	0.071	0.016	0.162	4.477	0	0.04	0.102
Number of Restaurant Commuters	-0.22	0.054	-0.207	-4.074	0	-0.327	-0.114
Number of Mosques	-118.766	42.68	-0.103	-2.783	0.006	-202.543	-34.989
Parking (m2)	-0.009	0.005	-0.071	-2.021	0.044	-0.018	0
R^2	0.275						
Adj. R^2	0.269						

Table 23: Results of Multiple Linear Regression – (Dependent Variable: Average Daily Boarding and Alighting)

Dependent Variable: Average Daily Boarding							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-9.765	-9.765		-0.853	0.394	-32.245	12.715
Number of Shopping Places	16.637	2.338	0.258	7.116	0	12.049	21.226
Personal Business (Number)	0.006	0.002	0.139	3.902	0	0.003	0.009
Shopping Commuters	0.008	0.001	0.384	6.512	0	0.005	0.01
Total Residents	-0.009	0.002	-0.212	-4.888	0	-0.013	-0.005
Number of Restaurant Commuters	-0.014	0.006	-0.129	-2.504	0.012	-0.026	-0.003
R^2	0.206						
Adj. R^2	0.201						

Dependent Variable: Average Daily Alighting							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	13.895	9.148		1.519	0.129	-4.06	31.85
Shopping Commuters	0.006	0.001	0.452	7.7	0	0.004	0.007
Number of Shopping Places	10.2	1.527	0.251	6.681	0	7.203	13.197
Total Residents	-0.003	0.001	-0.116	-2.413	0.016	-0.006	-0.001
Personal Business (Number)	0.004	0.001	0.124	3.538	0	0.002	0.005
Number of Restaurant Commuters	-0.014	0.004	-0.197	-3.87	0	-0.021	-0.007
Number of Mosques	-7.477	2.81	-0.098	-2.661	0.008	-12.992	-1.962
R^2	0.239						
Adj. R^2	0.234						

Table 24: Results of Multiple Linear Regression – (Dependent Variable: Average Weekday Boarding and Alighting)

Dependent Variable: Average Weekday Boarding							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-9.409	10.333		-0.911	0.363	-29.69	10.871
Number of Shopping Places	15.052	2.109	0.258	7.137	0	10.913	19.192
Personal Business (Number)	0.006	0.001	0.145	4.083	0	0.003	0.009
Shopping Commuters	0.007	0.001	0.39	6.634	0	0.005	0.009
Total Residents	-0.008	0.002	-0.204	-4.72	0	-0.011	-0.005
Number of Restaurant Commuters	-0.014	0.005	-0.134	-2.61	0.009	-0.024	-0.003
R^2	0.213						
Adj. R^2	0.208						

Dependent Variable: Average Weekday Alighting							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	12.759	8.518		1.498	0.135	-3.96	29.478
Shopping Commuters	0.005	0.001	0.458	7.824	0	0.004	0.007
Number of Shopping Places	9.402	1.422	0.248	6.614	0	6.612	12.193
Total Residents	-0.003	0.001	-0.11	-2.295	0.022	-0.005	0
Personal Business (Number)	0.003	0.001	0.128	3.672	0	0.002	0.005
Number of Restaurant Commuters	-0.013	0.003	-0.2	-3.941	0	-0.02	-0.007
Number of Mosques	-6.98	2.616	-0.098	-2.668	0.008	-12.116	-1.845
R^2	0.245						
Adj. R^2	0.239						

Table 25: Results of Multiple Linear Regression – (Dependent Variable: Average Weekend Boarding and Alighting)

Dependent Variable: Average Weekend Boarding

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	-12.905	18.35		-0.703	0.482	-48.922	23.111
Number of Shopping Places	23.791	3.909	0.234	6.085	0	16.117	31.464
Personal Business (Number)	0.009	0.003	0.132	3.558	0	0.004	0.015
Shopping Commuters	0.011	0.002	0.345	6.185	0	0.008	0.015
Total Residents	-0.016	0.003	-0.229	-5.097	0	-0.022	-0.01
Number of Employees	-0.006	0.003	-0.105	-2.147	0.032	-0.011	-0.001
R^2	0.180						
Adj. R^2	0.175						

Dependent Variable: Average Weekend Alighting

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Variables	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	20.643	13.041		1.583	0.114	-4.953	46.239
Shopping Commuters	0.008	0.001	0.426	7.13	0	0.006	0.01
Number of Shopping Places	14.94	2.176	0.262	6.864	0	10.668	19.212
Total Residents	-0.005	0.002	-0.139	-2.841	0.005	-0.009	-0.002
Number of Restaurant Commuters	-0.018	0.005	-0.184	-3.553	0	-0.028	-0.008
Personal Business (Number)	0.004	0.001	0.106	2.977	0.003	0.001	0.007
Number of Mosques	-10.426	4.005	-0.098	-2.603	0.009	-18.288	-2.564
R^2	0.215						
Adj. R^2	0.210						

The results of the analysis revealed the following:

- The land use parameters are the most significant in terms of impact on stop level ridership.
- The infrastructure parameters have minimal impact on the ridership.

In addition, the assessment of the parameters against the various dependent variables revealed the following:

- The most significant parameters can be summarized in six (6) independent variables. These are Number of Shopping Places, Personal Business, Shopping Commuters, Total Residents, Number of Restaurant Commuters, Number of Mosques. In addition, the analysis showed that there are some variables that rarely affect the ridership on few occasions, those are, the Parking Area, and the Number of Employees.
- The most significant parameters against the Average Hourly, Daily, and Weekday Boarding are Number of Shopping Places, Personal Business (Number), Shopping Commuters, Total Residents, then Number of Restaurant Commuters. However, for the Average Weekend Boarding, the analysis showed that the Number of Restaurant Commuters have no impact, and instead, the Number of Employees is showing the impact. The results for the Average Weekend Boarding looks unreasonable, however, it can be justified that during weekends, the employees working in shifts could use the bus system as the rest of activities are considered minimal in the areas of with higher employment than the other area.

- Shopping Commuters, Number of Shopping Places, Total Residents, Personal Business, Number of Restaurant Commuters, and Number of Mosques are the most effective parameters on both the Average Hourly and Daily Alighting. However, the analysis has shown that the parking area has also an impact on the Average Hourly Alighting.
- In terms of the Average Weekday Alighting, the most significant parameters are Shopping Commuters, Number of Shopping Places, Total Residents, Personal Business, Number of Restaurant Commuters and Number of Mosques.
- While for the Average Weekend Alighting, the most significant parameters are Shopping Commuters, Number of Shopping Places, Total Residents, Number of Restaurant Commuters, Personal Business and Number of Mosques.

The most significant parameters that were common in all the above-listed points are the Shopping Commuters and Number of Shopping Places. These results have been illustrated earlier in this Chapter in the high-level assessment as shown in Figure 30 and Figure 31.

The Parking Area was the only significant parameter when compared with the other infrastructure parameters. This can be understood due to the fact that there is no other mode of transport in Qatar that integrate with the bus service, as such the use of passenger cars and taxis, is needed to allow for this integration. It was expected that the footpath would show the highest significant parameter, however, that was not the case.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Qatar is one of the fastest growing countries in the world. Per records from the Ministry of Development Planning and Statistics (formerly the Statistics Authority), Qatar's population in 2004 was (744,029), and due to many factors, economic growth, oil and gas boom in the country, the population has grown up to (2,477,113) 300% increase when compared to 2004 (MDPS, 2016). This growth has resulted in a substantially larger private vehicle usage leading to congestion. Based on current surveys, the private car usage is about 85% of total traffic, and the remaining 15% includes the Public Buses, Taxis, Company Buses, etc.

Hosting the World Cup 2022 required a huge investment in the development of the real-estate sectors in the country leading to the need for proper infrastructure catering for the excessive demand from those developments. As such, Qatar is spending millions every year to deliver a world class road and public transport network to cater for such excessive demand and satisfy the public requirements in terms of accessibility and mobility.

To satisfy the above requirements and to accommodate the growth in population, reduce congestion as well as the private car usage in Qatar, the government has initiated the first Public Transport Company, named Mowasalat (KARWA). In 2005 Mowasalat has launched the first bus service with 5 routes and 15 buses, and until 2008 the system was in its preliminary stages. In the 2nd quarter of 2008, Mowasalat has launched the Karwa Smart Card to manage the fare collection and service ridership. The smart card data is uploaded to a fare collection system called (Kentkart) that monitor the operation of the bus service and record the number of passengers and revenues per cardholder per line and stop. By the end of 2016, Mowasalat Bus Network was expanded to cover the entire State of Qatar with 51 lines and over 1100 stops. With this network, the current bus service is experiencing below expectations ridership (Mowasalat, 2017). The bus system is mainly used by the expatriate community and the low-income people (Shaaban & Khalil, 2013) and specific professions, due to Qatar Traffic Law where per an article published in the local newspaper, 140 professions are not allowed to obtain a driving license (Newspaper, 2013).

Qatar, currently have 85% of transport and trips are made by cars, and about 6.5% are done by a public transport mode, mainly the bus system, while the remaining percentage includes other transport modes like, taxis, cycling…etc (MOTC, 2018). However, when comparing the public transport ridership in the country against different countries, Qatar, as one of the Gulf Region Nations, have the common rate for public transport, for example, during 2007, only 7% of people journeys in Dubai were done by public transport (Clarke, et al., 2007), while in Hanoi, Vietnam, as a developing country, the public transport share during 2009 did not exceed 10%.

And when compared with the US, 7% of Los Angeles population between 2008-2012 use the public transport systems, while 72% drive alone to work (Zhuang, 2014). Table 26 shows the ranking of US counties share of public transport.

Table 26: Ranking Public Transport Mode Share by County in U.S

Rank	Percentage of Population Taking Public Transportation to Work	Country/ Population/ Notes
1	60.80%	Kings, NY/ 2,512,740/ Brooklyn
2	58.40%	New York, NY/ 1,596,735/
3	58.30%	Bronx, NY/ 1,386,364
4	51.70%	Queens, NY/ 2,235,008
5	39.20%	Hudson, NJ/ 636,194
6	37.80%	District of Columbia, DC/ 605,759
7	32.40%	San Francisco, CA/ 807,755
8	31.80%	Suffolk, MA/ 724,502
9	29.70%	Richmond, NY/ 468,374/ Staten Island
10	27.50%	Arlington, VA/ 209,077
11	26.30%	Philadelphia, PA/ 1,525,811
…	…	…
16	17.70%	Cook, IL/ 5,197,677/ Chicago
…	…	…
65	7.10%	Los Angeles, CA/ 9,840,024

Source: American Community Survey dataset for 2008 – 2012 (United States Census Bureau, 2014) (Zhuang, 2014)

From previous studies, many factors are affecting the public transport operation and ridership. These factors are presented earlier and can be grouped into three (3) categories: (1) built infrastructure, (2) land use and population, and (3) surrounding conditions. Under each category, several independent parameters have been employed to conduct the analysis and identify what are the main factors affecting the bus ridership in the country. For example, the built infrastructure in Qatar includes a wide variety of layers that would affect the accessibility to the bus facilities and the ridership consequently. On the other hand, the variety of the land use types from residential to commercial and offices has a major impact on the ridership, as it identifies the origin and destination of the public transport demand in the system. The last category is led by the passengers' behavior and their ability to use the public transport facilities during the good and harsh conditions.

The study period data has been collected from several sources covering the entire country. Each source has been contacted, approached and met with representatives to obtain the relevant data for the corresponding study period. The data has been reviewed, assessed and verified prior to conducting any analysis to make sure that proper data has been collected and reflecting the actual situation during the corresponding study period. More details are provided in the body of this report.

6.1. Macroscopic Level Assessment

In the part of the Macroscopic Level Assessment, the system-wide ridership over the period from the year 2012 to the year 2016 has been assessed against several parameters, as the ridership had gradually increased from the year 2012 – 2013, but dropped in 2014 and 2015 then increased to its highest in 2016. As such, this fluctuation in the ridership was assessed against the network expansion, population, day of the week and the weather.

The analysis had revealed the following:

- The population had a diverse impact on the ridership against the population, and instead of having an increase in the ridership along with the population, it was surprisingly decreasing starting in 2014 to its lowest in 2015 and increased again in 2016.
- The network expansion has resulted in diverting the passengers to the new lines introduced over the study period. This is compatible with Liu et al. (Liu, et al., 2017), where they have concluded that introducing new lines has resulted in diverting the passengers to the new lines and stations. In addition, passenger flow varied with time on the existing lines and stations.
- In terms of the days of the week assessment, the assessment was conducted over the study period (2012 – 2016) to show the ridership trend over the study period. The highest ridership was over the weekend mainly Fridays followed by Thursdays. This result clarifies that most of the passengers have the common rest days and behavior. The results of this assessment were incompatible with Yetiskul and Senbil (Yetiskul & Senbil, 2012) who have resulted the highest ridership was over the weekdays in Turkey.
- Assessing the ridership against the weather required first the comparison of the monthly ridership over the study period. The highest ridership occurred during the month of November and the lowest was during the month of July or the summer season in general (July, August, and September). This would be due to the hot weather during the summer. This is compatible with the results of studies that has

been conducted in Doha, where the pedestrian volume is considered the lowest during the summer season (Shaaban & Muley, 2016) (Shaaban, et al., 2017). However, the results again are incompatible with Arana et al. (Arana, et al., 2014) who's study was conducted in Spain, and their results have shown that when the temperature rises, the number of passengers increased compared to Qatar where it has dropped drastically during the summer season. For the ridership trend against the precipitation rates in Qatar, it has shown similar trend during the summer and showed a drastic drop in the ridership with the drop in the rainfall, which again was different if compared to Arana et al. However, to provide a better explanation about the weather impact, the daily ridership for year 2016 was assessed against the daily weather data including temperature, humidity, visibility, rain, wind…etc.

6.2. Mesoscopic Level Analysis

The 2016 boarding and alighting data was collected, and analyzed to understand the trend of the boarding and alighting over the different periods of the year (hourly, daily, weekdays and weekends). The study revealed that the month of December was the highest month during the year 2016, and Friday was the highest day during the week. The study also revealed that the AM peak hour was between 07:00 am – 08:00 am for both boarding and alighting, but it varied for the PM peak (Boarding PM Peak 05:00 pm – 06:00 pm and Alighting PM Peak 06:00 pm – 07:00 pm).

The initial analysis has revealed the following:

- The highest route in terms of both boarding and alighting was the route (76) as it starts from Al Ghanim Station (Stop 600) located in the Doha Down Town passing by the Corniche and the West Bay area.
- The highest stop in terms of boarding and alighting was the stop (600). The reason for the high boarding and alighting was due to the fact that most of the routes (38 routes) are either starting, passing or terminating at this station, in addition to its location within the downtown area where most of the activities, banks, shops, offices, and shopping places are located close by.
- Stops 600, 11 and 1800 are common in all statistics with the highest boarding and alighting passengers in all periods. The reasons to have Stops 11 and 1800 with high ridership is due to their locations. For example, stop 11 is located in front of the City Center Mall in the West Bay Area and many lines passing through this stop in addition to the type of activities and land use in the vicinity of the mall. While stop 1800 is located in the Industrial Area where most of low income employees are residing or working in that area. The rest of stops varies based on various elements, like location, period, Number of lines, and type of lines.
- Most of the highest stops in terms of daily, weekday and weekend boarding and alighting are located in the industrial area and the surrounding zones, like, Stops Number (1800, 5000, 6000, 56661, 5542, 55641 and 55783).
- From on-site observations, most of the bus passengers during weekends are labors and people with low-income, who have Friday as a common weekend. Stops

Number (5696, 5698, 6000, 8893 and 55783) have the highest boarding during weekends.

- Any stop with high value in any of the infrastructure parameters does not mean that the rest are the highest.
- The boarding and alighting is not influenced greatly by the infrastructure parameters;
- Population and land use parameters have an influence on the ridership.

Multiple Linear Regression (MLR) analysis was used to estimate boarding and alighting on different levels based on the bus infrastructure, population, and planning--related attributes. Different parameters were included in the model and can be classified as (1) Infrastructure Parameters – Road Length, Bike Lanes, Footpath and Parking, (2) Planning and Land Use Parameters – Number of employees, Residents, School Students, No of Schools, University Students, Number of Mosques, Number of Restaurants, Restaurants commuters, leisure commuters, etc., and (3) Bus Operation Parameters and Network. The data was collected from several agencies and compiled in a Geographical Information System (GIS) map to understand the correlation between the parameters and to better presentation of the data.

The assessment of the parameters against the various dependent variables revealed the following:

- The most significant parameters can be summarized in six (6) independent variables. these are Number of Shopping Places, Personal Business, Shopping Commuters, Total Residents, Number of Restaurant Commuters, Number of

Mosques. In addition, the analysis showed that there are some variables that rarely affect the ridership on few occasions, those are, the Parking Area, and the Number of Employees.

- The most significant parameters against the Average Hourly, Daily, and Weekday Boarding are Number of Shopping Places, Personal Business, Shopping Commuters, Total Residents, then Number of Restaurant Commuters. However, for the Average Weekend Boarding, the analysis showed that the Number of Restaurant Commuters have no impact, and instead, the Number of Employees is showing the impact. The results for the Average Weekend Boarding looks unreasonable, however, it can be justified that during weekends, the employees working in shifts could use the bus system as the rest of activities are considered minimal in the areas of with higher employment than the other area.
- Shopping Commuters, Number of Shopping Places, Total Residents, Personal Business, Number of Restaurant Commuters, and Number of Mosques are the most effective parameters on both the Average Hourly and Daily Alighting. However, the analysis has shown that the parking area has also an impact on the Average Hourly Alighting.
- In terms of the Average Weekday Alighting, the most significant parameters are Shopping Commuters, Number of Shopping Places, Total Residents, Personal Business, Number of Restaurant Commuters and Number of Mosques.

- While for the Average Weekend Alighting, the most significant parameters are Shopping Commuters, Number of Shopping Places, Total Residents, Number of Restaurant Commuters, Personal Business and Number of Mosques.

The results of the analysis are compatible with other studies (Johnson, 2003) (Sun, et al., 2016) (Sohn & Shim, 2010) (Chakour & Eluru, 2016) (Kuby, et al., 2004) (Kamruzzaman, et al., 2014).

6.3. Recommendations

6.3.1. Public Transport Network Expansion:

The current development of the country is offering a significant enhancement to the public transport and increase the choice available to residents and visitors to the State of Qatar. The major improvements in terms of public transport are listed herewith:

- Doha Metro: the under-construction metro system with three lines (Phase 1) (Figure 32) will extend for over 70 km and serve 37 stations. All Phase 1 stations are planned to open by 2020.
- Lusail Light Rail Transit (LRT): Lusail will be served by the Lusail LRT system. The LRT system extends for 28 km and comprises three lines served by 28 stations at-grade and seven underground stations.

The station locations and features, as well as the metro's features, gender, the number of daily trips, the purpose of trips, and the average duration of trips in Doha might be significant factors that affects commuters' willingness to use the new metro system. In addition, the integration of the above systems with an enhanced bus transit system will cause an increase in the ridership. (Kuby, et al., 2004) (Chakour & Eluru, 2016) (Shaaban & Hassan, 2014).

Figure 32: Doha Metro – Phase 1

6.3.2. Bus Operation

The study revealed that most of the passengers are from low income and labor population. As such, the following strategies shall be considered in the development of the bus system in the country:

- Introduce a new strategy for the bus service as customer service instead of transport facility to attract more people to use the bus system in the country. This would include, introduce a free wi-fi service for all users, and introduce seating classes like air travel by offering Special waiting lounge, journals and magazines, choice of entertainment (movies and music), ample legroom, and free earphones. This approach is similar to Spain Strategy to improve the public transport system (BUSBUD, 2014).
- Decrease the walking and waiting time. (Shaaban & Khalil, 2013)
- High Occupancy Lanes or dedicated bus lanes shall be considered in the development of any road scheme where buses are planned to pass through. (CIVITAS Secretariat , 2010).
- Queue Jumping Lanes through signalized intersections is recommended where possible, to give the buses the priority through the congested intersections and allow them to follow their planned schedule. (CIVITAS Secretariat , 2010) (Shaaban & Ghanim, 2018).
- Proper bus laybys and shelters shall be implemented where applicable and on stops with high ridership. (CIVITAS Secretariat , 2010)

- Follow Mowasalat Guidelines in the design of the bus stops and allocate the bus stops accordingly. (Mowasalat, 2013)
- Increase the bus stations and distribute them among the entire network. this will relief Al Ghanim Station and reduce the number of lines passing through.
- Provide separate female waiting areas, prayer areas, and toilets at all main stations. (Shaaban & Khalil, 2013)
- Introduce Park & Ride facilities in the vicinity of the stations to allow passengers to park their vehicles and reduce congestion in the center by increasing the bus patronage.

6.3.3. Land Use

Most of the studies have resulted that the land use mix has major impact on the public transit ridership, (Chakour & Eluru, 2016) (Estupin˜a´n & Rodrı´guez, 2008) (Johnson, 2003) (Zhuang, 2014) (Sohn & Shim, 2010) and others, which is in line with the results of the current study. However, from the assessment conducted for this study, it was revealed that most of the higher ridership stops are located near either industrial area or areas with low-income residents and labor accommodation (Stops Number 1800, 5000, 6000, 56661, 5542, 55641 and 55783). As such, the following is recommended in terms of land use policies:

- Introduce Transit Oriented Developments (TOD) or Transit Adjacent Developments (TAD) in the vicinity of the Bus Stations. These areas shall be affordable similar to Mesaimeer Residential Complex.

- The developers of the TODs or TADs shall consider proper land use mix to increase the attractiveness of those sites.
- Increase the intensity of the bus stops in the areas of the labor accommodation, to allow them to use the bus system easily and improve the accessibility to the stops.

6.3.4. Infrastructure:

In terms of the infrastructure, the current system lacks the minimum bus infrastructure required to operate sufficiently, for example:

- Improve the availability of the footpath and bike lanes facilities in the vicinity of the bus stops to improve the pedestrian access to the stops. (Shaaban & Khalil, 2013)

6.4. Study Limitations

Once the study initiated in July 2016, the study team tried to identify the dependent variables in accordance with past studies. Accordingly, several agencies were approached to identify the available data and compare it against the past studies.

Once the parameters were identified, the received data was limited to a specific period, that would not be sufficient to conduct the assessment. Which required another 6 months to obtain the relevant data and commence the analysis. In addition, the format of the collected data required an extensive effort to suit the study purpose.

Furthermore, the GIS showed a difference in the Number of Places and the corresponding population groups within the catchment area due to the fact the catchment area calculates a percentage of the population when intersects with zones that could include the concerned places but outside the catchment area.

One of the limitations of the study was not including information about other transport modes along the corridor such as taxi due to the difficulty to obtain. Such parameters would affect the ridership in addition to the identified parameters. This can be further assessed if such information is collected in the future.

One of the parameters that would support the study is the demographic data obtained from the census. This shall be further studied in detail to illustrate the impact by studying the demographic parameters of the population, income and population characteristics on the ridership.

The study was limited to two levels, macroscopic and mesoscopic levels assessment, which illustrates that more work in future studies considering details of stop level ridership at the Microscopic Level considering the bus operation data and the pedestrian accessibility index.

Furthermore, future studies shall focus on the network expansion effect by considering the added routes and stops each year and focusing on the passengers shift to the new routes and passengers' behavior by studying their origin and destination. In addition, the impact of other transport modes on the bus operation shall be studied.

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