# BUS RAPID TRANSIT SYSTEM AND LAND-USE RELATIONSHIP WITH MODE CHOICE

Submitted in partial fulfilment of the requirement for the award of the degree of

**Doctor of Philosophy**

by


**Khalil Ahmad Kakar**

Roll No. 717008


Supervisors

Prof. C.S.R.K Prasad


**DEPARTMENT OF CIVIL ENGINEERING**

**NATIONAL INSTITUTE OF TECHNOLOGY**

**WARANGAL-506004, INDIA**


**OCTOBER-2023**

## NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

# CERTIFICATE

This is to certify that the thesis entitled "**Bus Rapid Transit System and Land-Use Relationship with Mode Choice**" being submitted by **Mr. Khalil Ahmad Kakar** for award of the degree of Doctor of Philosophy to the Faculty of Engineering and Technology of **National Institute of Technology Warangal** is a record of bonafide research work carried out by his under my supervision and it has not been submitted elsewhere for award for any degree.

**Prof. C.S.R.K Prasad**
**Professor (HAG)**
**Thesis supervisor**

# Declaration

This is to certify that the work presented in the thesis entitled "**Bus Rapid Transit System and Land-Use Relationship with Mode Choice**" is a bonafide work done by me under the supervision of **Prof. C.S.R.K Prasad** and was not submitted elsewhere for the award of any degree.

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have nor misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Khalil Ahmad Kakar

Roll No. 717008

Date:

# Acknowledgments

Embarking upon this doctoral journey has been a transformative experience, which would not have been possible without the support and encouragement from many quarters.

Foremost, I express my profound gratitude to **Prof. C.S.R.K Prasad,** whose guidance and encouragement have been pivotal in navigating through the complexities of this research. His relentless faith in my capabilities and insightful discussions have immensely enriched this work.

Heartfelt thanks to the members of the Doctoral Scrutiny Committee, **Prof. L. Krishnanad, Dr. K. V. R. Ravi Shankar, and Dr. Arpan Mehar**, for their support and invaluable at various stages of this doctorate journey. Special appreciation is extended **to Dr. S. Shankar**, whose help and encouragement have been a comforting constant, transforming challenges into achievements during my research journey and also my heartfelt gratitude to **Prof. Venkaiah Chowdary** for his support throughout my research journey.

My earnest thanks to the Heads of the Department of Civil Engineering, who have facilitated a conducive and supportive environment during my tenure here. I extend my sincere gratitude to the India Council for Cultural Relations and Government of India. My journey was enriched by the companionship of my friends, **Dr. Prashanth Shekar Lokku, Dr. T. Arjun Kumar, Dr. D. Abhigna, and Dr. K. Srikanth,** whose encouragement and camaraderie, especially during my initial days in India, have been a source of constant strength. Gratitude is also extended to the faculty and staff of the NITW, whose support and cooperation have been monumental during my course.

Above all, a special and emotional thank you to my wife, **Nazifa Kakar** my children, **Zahab Kakar, Suhail Kakar, Metra Kakar and Zahed Ahmad Kakar** and my entire family, whose unwavering faith, financial, and emotional support have been my anchor throughout this journey. Your sacrifices, patience, and endless encouragements have been the driving force behind my perseverance. In reflecting upon this journey, these acknowledgments serve not merely as expressions of gratitude but as testament to the collective efforts of all those who have walked this path with me. My journey has been enriched by the wisdom, support, and kindness you have generously shared.

Thank you.

**Khalil Ahmad Kakar**

# Approval Sheet

This thesis entitled "**Bus Rapid Transit System and Land-Use Relationship with Mode Choice**" by **Khalil Ahmad Kakar** is approved for the degree of Doctor of Philosophy

**Examiners**

______________________________

______________________________

______________________________

______________________________

**Supervisor**

______________________________

**Chairman**

______________________________

**Date:**

# Abstract

The key aims of this study are to examine models for describing the possibilities of Bus Rapid Transit system (BRT) system and the association among land-use and transport modal choice. Kabul and Jalalabad were considered as study areas. These cities are the most significant metropolitan areas in Afghanistan in terms of traffic and urban form. In the analysis and modeling of Kabul's urbanization and transportation systems, the geographic unit used is the municipal area of Kabul, which spans 1,025 km² and comprises 22 districts. In order to achieve accurate results, the city was divided into 213 traffic zones. Hence, traffic zone is the unit for analysis.

For Jalalabad city, disaggregate Stated Preference (SP) data were collected through a survey along the PT routes to analyze the mode shift from the current modes to the proposed BRT system.

A preliminary survey revealed a lack of sufficient and efficient high-capacity public transport (BRT) systems in both cities. Additionally, segregation between land-use and thetransportation system in Kabul city has created problems such as congestion, a high level of accidents, and air pollution. To evaluate the possibilities for an efficient BRT system, key concepts such as travel demand, modal shift, and affiliation among land-use and trip behaviours must be analysed. Various factors can affect these concepts, including household characteristics, travel features, and characteristics of the built environment.

Urban Travel Demand Modelling (UTDM) study for Kabul utilized various tools to understand the city's travel behaviours. Through multiple linear regression, key factors such as population, job availability, car ownership, and urban density were recognized as major influences on trip-making. The majority of journeys appeared to start from the suburban areas and move towards the Central Business District (CBD). Using the Gravity Model, trips between 213 traffic zones were analysed, highlighting the main travel paths in the city. The study also looked into Kabul's transportation choices and noticed a preference for smaller vehicles. With the help of the Logit curve function, these travel preferences became more apparent. The rise in small vehicles poses a challenge for the city's transportation network. To address this, there's a suggestion to introduce an advanced BRT system to reduce the reliance on these smaller vehicles. As a part of this research, possible BRT routes were assessed to match travel needs. Among them, the All-or-Nothing model identified route 23 as the best candidate for a BRT, connecting Kabul airport to the city core.

Modal shift is a fundamental concern when introducing a competent BRT system. Therefore, it

was necessary to develop a modal shift model to understand the influential variables. The research identified crucial elements associated with the viability of the BRT system. The suggested BRT system is anticipated to attract a considerable number of passengers form cars, share taxis, and personal transport means. The transition to BRT is profoundly shaped by factors such as journey and wait durations, distance to stations, the presence of air conditioning, the motives of the commuters, and gender considerations might catalyse a notable shift of users

from low-capacity vehicles (LCVs) to the BRT. It has spotlighted pivotal elements driving the transition from LCVs to the advocated BRT system. The data gathered in this research demonstrates that many low-capacity vehicle users, including those using cars in Jalalabad city, are dissatisfaction with the current state and would likely consider this new transit alternative. The last part of study investigates into the relationship between urban compactness and transportation preferences in Kabul's 213 traffic zones using the mode choice model. Evaluating urban compactness, the research considers land use diversity and demographic densities. Using metrics. it identifies districts with high, low, or sprawling compactness levels. Results highlight a clear trend: densely populated areas like Bibi Mahroh and Khair Khana witness a greater inclination towards walking and public transport. In contrast, sprawling regions such as Paimonar and Reshkhor see a preference for private vehicles. The study confirms that urban layout significantly influences transportation trends, with sprawling areas showing a reduced tendency to utilize public transport or walking. The thesis aims to explore the impact of Bus Rapid Transit (BRT) systems on urban mobility, specifically examining how BRT influences the mode choice among urban residents. It contributes to the body of knowledge by providing empirical evidence on the efficacy of BRT systems in encouraging a modal shift from private vehicles to public transport, and examines the relationship between the built environment and mode choice.

# Tabe of Contents

## List of Figures

# List of Tables

| Table No. | Pg.. No |
|---|---|

# Abbreviations

| | |
|---|---|
| GDP | Gross Domestic Product |
| LCV | Low-Capacity Vehicle |
| PT | Public Transport |
| NMT | Non-motorised Transport |
| HRT | Heavy Rail Transit |
| LRT | Light Rail Transit |
| MRT | Mass Rapid Transit |
| CBD | Central Business Districts |
| ITS | Intelligent Transportation System |
| MP | Master Plan |
| TOD | Transit-Oriented Development |
| HCV | High-Capacity Vehicle |
| LCV | Low-Capacity Vehicle |
| TCQSM | Transit Capacity and Quality of Service Manual |
| MRT | Mass Rapid Transit System |
| IMPACT | Mobility Impact Index |
| SOV | Single-Occupancy Vehicle |
| BMA | Bangkok Metropolitan Administration |
| VKT | Vehicle Kilometre Travelled |
| HTS | Household Travel Survey |
| GIS | Geographic Information System |
| NTS | National Travel Surveys |
| NPTS | Nationwide Personal Transportation Survey |
| BMA | Bangkok Metropolitan Administration |

| | |
|---|---|
| MPW | Ministry of Public Works |
| MOTCA | Ministry of Transport and Civil Aviation |
| MBE | Millie Bus Enterprises |
| MBC | Millie Bus Company |
| TDM | Travel Demand Modelling |
| O-D | Origin-Destination |
| LLH | Log-Likelihood |
| LN | Log Normal |
| LULC | Land Use Land Cover |

# CHAPTER 1
# INTRODUCTION

## 1.1 General

Bus Rapid Transit (BRT) system, plays a pivotal role in sculpting a landscape that pleasantly merges transport proficiency with sustainable urban living. The inauguration of BRT, tracing back to Curitiba, Brazil in the 1970s, has transformed the global vista of urban transit, offering a feasible, efficient, and more environmentally friendly alternative to its low-capacity transport counterparts. While the BRT model, originating in Curitiba, Brazil, has since proliferated across approximately 200 municipalities worldwide, serving 33 million daily commuters (Wright and Hook, 2007), the applicative dynamics of BRT in diverse global contexts present a rich tapestry for exploration. BRT systems have emerged as a popular alternative to traditional transit modalities, offering an mixture of efficiency and sustainability.

Cities like Bogotá and Guangzhou have been heralded for their successful BRT implementations, demonstrating a potential blend of high service levels and economical feasibility in urban transportation (Cervero and Kang, 2011).

The shift from Low-Capacity Vehicles (LCVs) to BRT systems symbolizes a strategic effort to alleviate urban traffic congestion and reduce pollution from transportation. This modal shift goes beyond the physical utilization of different transport modes and encompasses the evolution of urban transport policies,infrastructural development, and communal perceptions towards transit systems. The BRT, with its inherent larger capacities and dedicated lanes, introduces a substantive alternative to traditionalbuses and extensive bus rapid transit systems, skillfully managing the dynamic demands of urbantransit (Hidalgo and Gutiérrez, 2013).

When talking about land use and choosing types of transportation, think about where people live and where they go, like work, school, or shopping. If houses, apartments, and offices are close to bus or train lines, more people might use these services instead of driving cars. So, where things are built (like homes and shops) and the kinds of transportation available, like buses, trains, or bike lanes, are connected. Making smart choices about where to put things and what kind of transport to offer can help make travel easier and better for everyone in the city. Thuse, this chapter carefully examines the BRT system, highlighting its crucial role in enhancing sustainable urban travel. The discussion explores global utilization of BRT systems, the essential shift from LCVs to larger transit systems, and the impactful relationship between land use and transportation choices in city planning. The need for this study arises from an urgent requirement to address growing urban challenges, such as traffic and pollution, while fostering sustainable development and efficient mobility. Clear objectives stand out.

### 1.2 Understanding the Impact of the Bus Rapid Transit System

Urban spaces globally confront substantial challenges in maintaining efficient and sustainable mobility, predominantly due to increasing population densities and vehicular traffic. BRT systems emerge as a pivotal solution, addressing the critical aspects of urban transport through delineated bus lanes, controlled fare systems, and enhanced service frequency (Wright, 2002).

The BRT system's inherent design, which includes dedicated lanes, off-board fare collection, and intersection treatments, alleviates urban congestion significantly. This methodology ensures that buses operate independently of general traffic, thereby reducing travel time and enhancing schedule adherence (Carrigan, 2013). Consequently, urban areas implementing BRT witness improved public transport reliability and an augmented modal shift from private vehicles to public transit (Levinson et al., 2002).

The economic aspects of BRT cannot be understated, offering both direct and indirect economic benefits. Directly, it offers an economical transit solution for urban dwellers and indirectly propels economic activities along the BRT corridors through increased accessibility to businesses (Rodríguez and Targa, 2004). Moreover, BRT systems, by necessitating fewer infrastructural modifications than rail systems, embody fiscal prudence in initial capital investment and ongoing operational costs (Levinson et al., 2003).

Environmental sustainability is unequivocally intertwined with urban transport. BRT systems inherently reduce vehicular emissions per passenger due to their elevated passenger capacity, thus contributing to the reduction of urban air pollution and the mitigation of greenhouse gas emissions (Vincent et al., 2005). Moreover, by serving as an effective alternative to automobile usage, BRTs contribute to lowering the overall vehicular emissions within the city (Eichler, 2006).In the realm of safety, BRT systems demonstrate a commendable reduction in traffic-related incidents due to the segregation of buses from general traffic and the incorporation of structured boarding facilities (Hidalgo and Carrigan, 2010). Thus, the meticulous design and operational strategies of BRT systems provide a confluence of rapid mobility, economic vitality, environmental sustainability, and safety within the urban transport framework.

BRT system has gained popularity due to its ability to provide high service levels at lower costs than Heavy Rail Transit (HRT), Light Rail Transit (LRT), and metro systems. Numerous South American cities have embraced BRT systems due to reduced construction costs. Originating in Curitiba, Brazil, in 1970, BRT implementations have markedly surged in the past decade, now featuring in approximately 200 municipalities and serving 33 million daily commuters globally.

Notably, 88% of these systems are found in South American and Asian nations (Global BRT Data, 2016). The prevalence of BRT systems is also rising in Europe, where they are commonly denoted as Buses with a High Level of Service (BHLS). As such, BRT systems operate in several European countries, including France, Greece, Spain, and the Netherlands. BRT systems vary considerably between cities, and many studies focus on the system's design concepts and characteristics. Some studies evaluate the impact of such characteristics on ridership for BRT (Ingvardson, 2017). Figure 1.1 displays the capacities of transport modes.

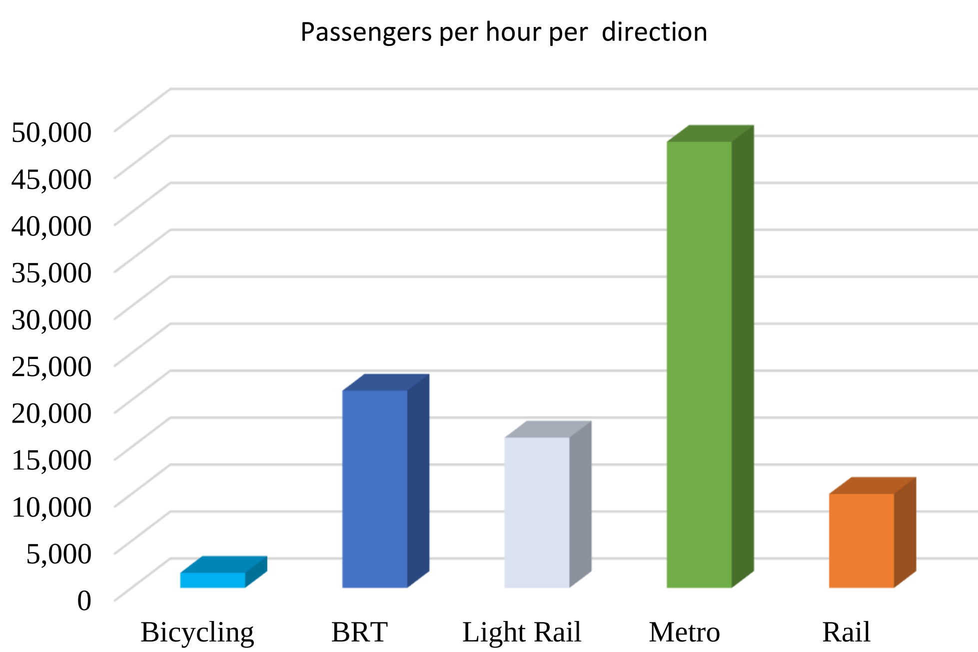



**Figure 1.1** Passenger capacity of different transport modes (TUMI 2018)

BRT is a method for providing high-quality, fast Public Transit (PT) services using rubber-tire vehicles. Buses aretypically standard 12-meter vehicles. However, in the face of higher demand, double and triple- articulated buses can be utilized, as seen in the BRT system in Curitiba, Brazil. Experiences have shown that BRT systems offer services similar to rail and LRT but at comparatively lower costs. This system fundamentally differs from local bus services regarding reliability, quality, amenities,speed, station types, corridor types, and fare collection methods.

Moreover, BRT systems can integrate Intelligent Transportation System (ITS) equipment, signal transit priority at intersections, and fare collection machines. This transit system operates on segregated or mixed rights-of-way along arterial and highway (Wright, 2007). Studies examining BRT systems' social, environmental, and economic impacts in Colombia, Mexico City, South Africa, and Istanbul concluded that BRT enhances the quality of life in urban areas in at leastfive key ways: travel time savings, mitigation of local air pollution emissions, traffic safety enhancement, increased physical activity, and meeting other social goals (Good Practice Guide, 2006). Meanwhile, two types of BRT systems are closed and open, distinguished by their design and operating features. Figure 1.2 shows the Quito Ecoia line with the segregated right-of-way.


**Figure 1.2** BRT system Quito Ecoia line (Lioyd Wright 2007)

Table 1.1 presents the characteristics and features of both types (Cervero, 2013).

**Table 1.1** Bus Rapid Transit system types

| Features | Closed BRT System | Open BRT System |
|---|---|---|
| **Right-of-way** | Allocated transit lanes; vertical segregation; preferential treatment at crossroads | Mixed-usage traffic channels; conventional intersection management |
| **Stops/Shelters** | Upgrade shelters to extensive, climate-controlled transport hubs | Stations, occasionally equipped with shelters, seating, illumination, and traveller information. |
| **Service Designs** | Persistent schedules; unified local and express transit; coordinated transfers | Conventional service layouts |
| **Fare Collection** | Exterior fare collection; intelligent card systems; multi-entry boarding | Classic fare mediums |
| **Technological Applications** | Automated Vehicle Location (AVL); traveller information networks; traffic light prioritization; vehicular docking/guidance mechanisms | Restrained technological deployments |

## 1.3 Advantages and Popularity of the Bus Rapid Transit System

In the last 20 years, sustainable public transport (PT) systems, like BRT, have seen remarkable development in developing countries. These extensive, urban-scale PT endeavours often become essential components of broader urban renewal plans, targeting the promotion of economic advancement and sustainable growth (Delmelle et al., 2012). The careful selection and strategic planning of BRT systems is imperative due to their significant impact on travel durations, service consistency, operational/maintenance expenses, environmental factors, and passenger appeal. BRT systems should be eco-friendly, mitigating air and noise pollution (Baghini et al., 2013). Additionally, BRT systems bring benefits, including low initial and operational costs providing quick responses to increasing mobility needs. Its capability to function without subsidies and adaptability to meet social needs have notably enhanced its political acceptance (Campbell et al., 2009). Experiences from BRT systems in Brazil and Colombia imply that these networks can supply services parallel to those of HRT and LRT systems, albeit at a markedly reduced expense.

Nevertheless, recent investigations into whether to develop BRT or LRT systems or primarily perceive BRT as an auxiliary route network reveal contradictions among urban specialists. Moreover, the formulation, execution, and administration of a BRT system are not uncomplicated and necessitate political leadership, societal concurrence, and adept technical and managerial capabilities. A variety of distinctive BRT design and technology structures, along with diverse fiscal and operational strategies, must be contemplated within the multifaceted nexus of urban planning and economics to synchronize with crucial urban policies like land use and intermodal amalgamation (Hensher, 1999; Hensher, 2007; Alpkokin et al., 2012).

BRT systems are perceived as a method to enhance socially sustainable transport. They are broadly acknowledged for amplifying urban mobility via various measures, including augmenting busways, providing proficient services, and upgrading the urban environment. The system has also surfaced as a pivotal strategy in battling climate change. The International Energy Agency advocates for implementing BRT systems with up to 25,000 km of new BRT lines globally, aspiring to satisfy urban mobility requirements while propelling global emission reduction objectives (IEA, 2013). The efficacy and efficiency of BRT modes have been showcased in numerous countries. For example, Seattle's BRT system has decreased road bus volumes by over 20%. BRT systems utilizing tunnels have witnessed 40% fewer traffic incidents than mixed-traffic services. Curitiba utilizes over 30% less fuel per capita for urban transport than other major Brazilian urban regions, while Bogotá's BRT system has registered 93% fewer accidents and a 40% decrease in pollutants during its initial five months of operation. Moreover, an improvement in the quality of life of Bogotá's low-income inhabitants, linked to savings in travel time and cost, has been noted (Wright, L. 2007).

Given these benefits, BRT systems have become increasingly popular in developing Asian countries, including Indonesia, Thailand, Vietnam, and the Philippines, which have initiated, planned, or are considering implementing BRT systems. However, effective BRT development in these countries involves addressing numerous local issues that largely contribute to the successful execution of BRT. In many developing Asian countries, where city planning is predominantly focused on road transport development and effective land use control is lacking, issues such as urban sprawl, traffic congestion, and air pollution emerge, implementing a BRT system in these conditions is notably challenging. Various research and guidelines concerning BRT systems have been formulated and recommended, drawing from successful experiences across diverse urban regions. Consequently, supplementary feasibility studies are necessary before initial BRT implementation (Satiennam, 2006). Figure 1.3 shows the impacts of TransMilenio BRT system on different factors. Furthermore, based on Institute for Transportation and Development Policy ITDP, Figures 1.4 and 1.5 show the global BRT systemridership and length.

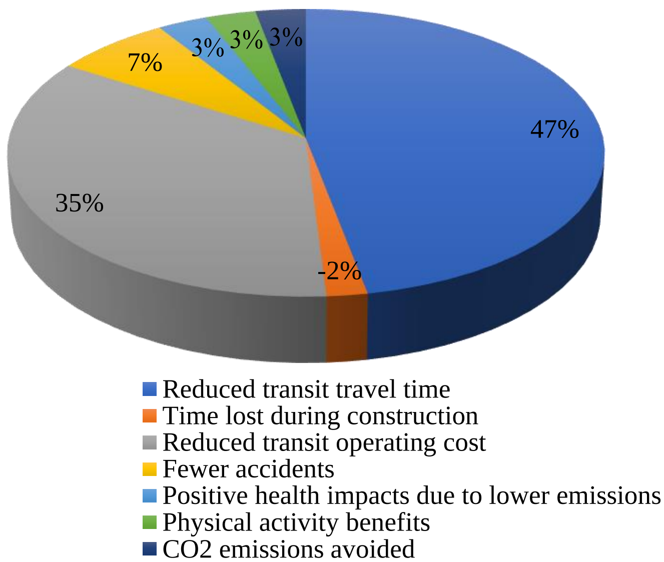



**Figure1.3** Trans Milenio BRT System impacts (EMBARQ 2009)

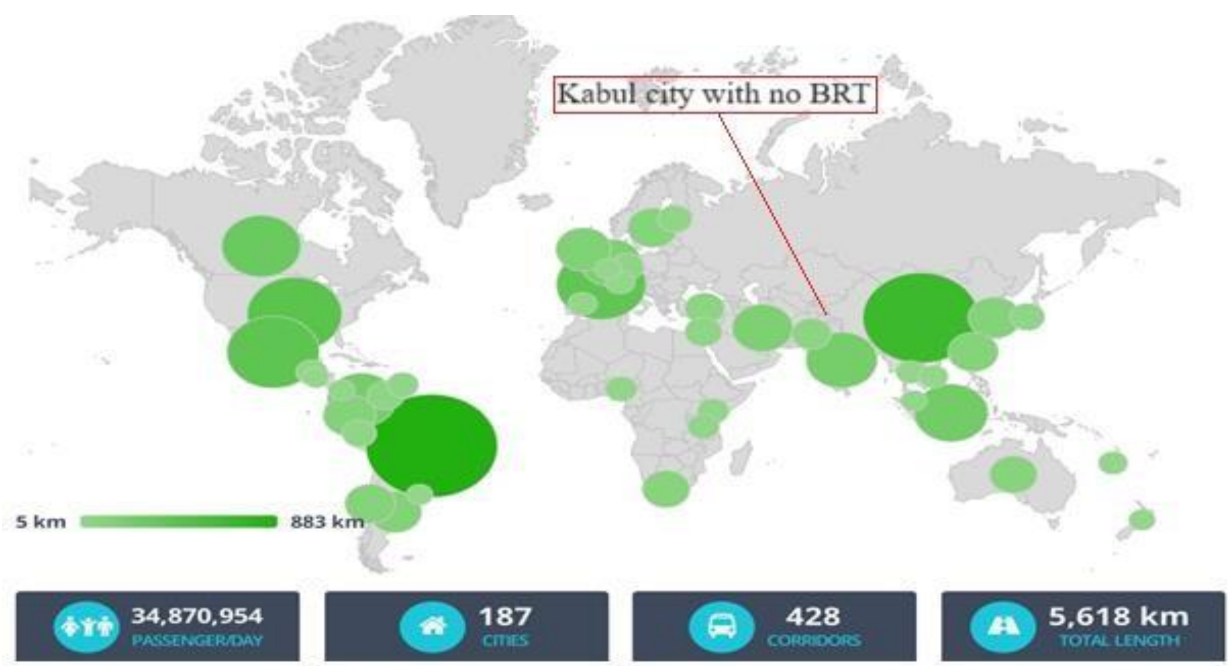



**Figure1.4** BRT system length (ITDP)

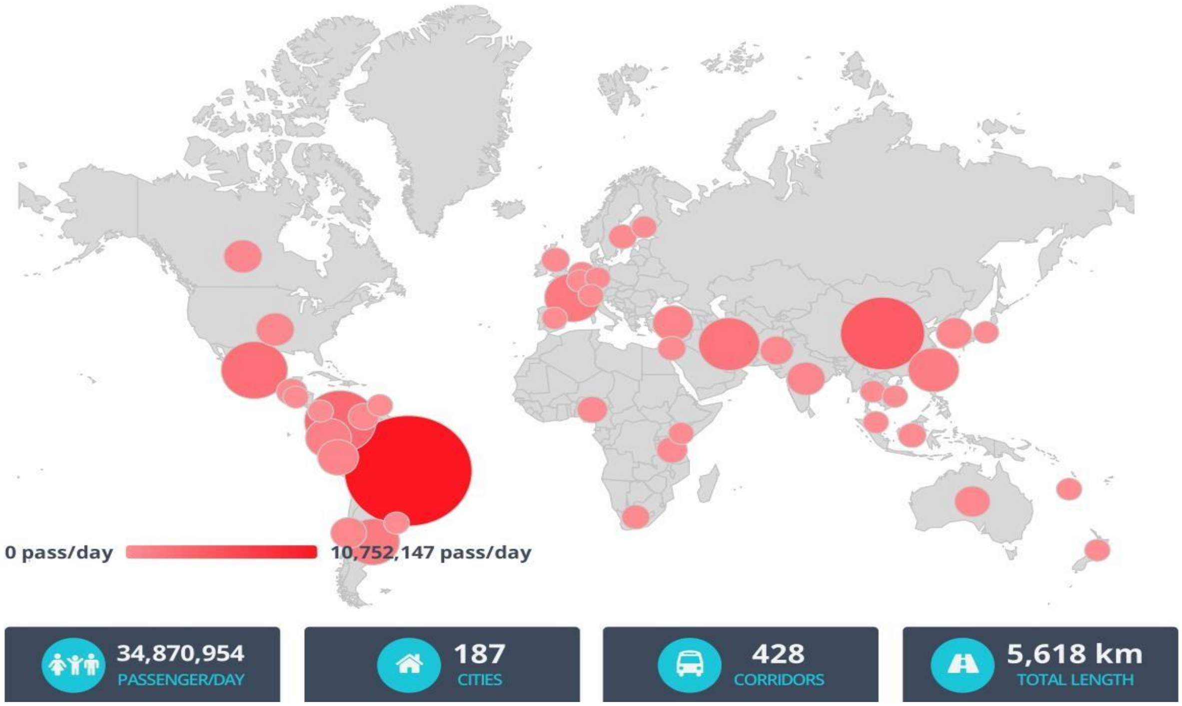



**Figure1.5** BRT system demand (ITDP)

From the data, it seems like Latin America dominates in all categories, it has the most passengers per day, the most cities, and the longest total route length (Table 1.2)

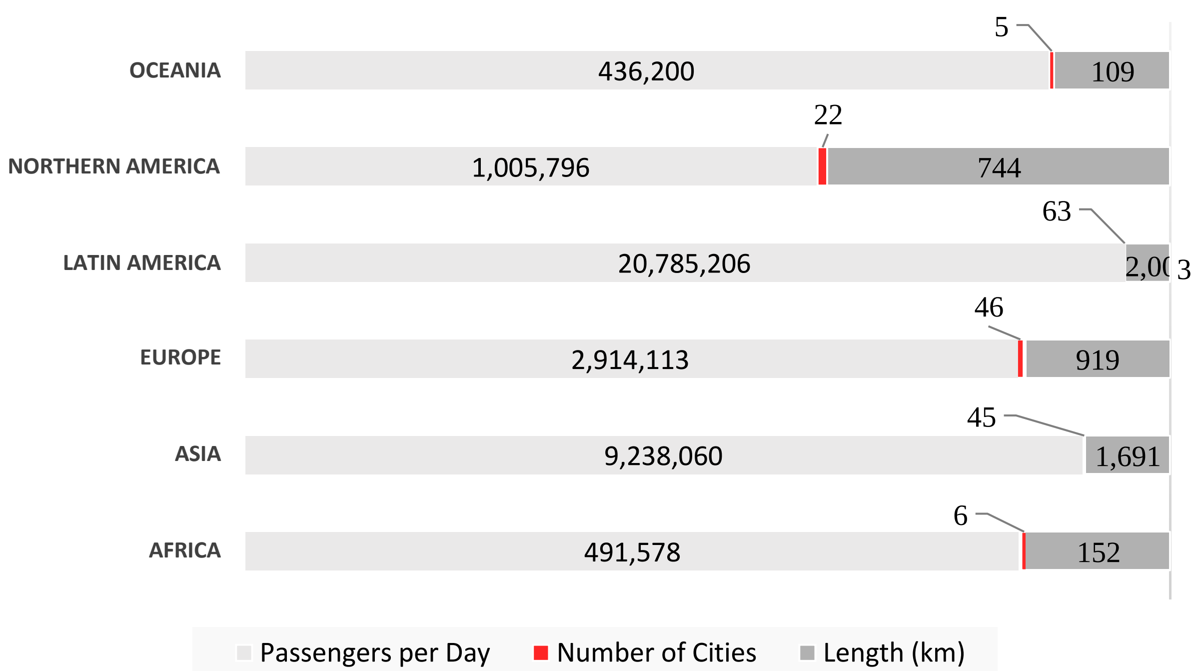



**Figure 1.6** Bus Rapid Transit system in the world

## 1.4 Travel Demand for Bus Rapid Transit System

Effective BRT designs are usually planned within a well-structured master plan (MP). The selection of BRT right-of-way is crucial. Not only can choosing the optimal corridor increase the number of beneficiaries of BRT investments, but a strategically chosen corridor can also promote transit-oriented development (TOD) under certain conditions, with profound effects on the city's future growth. The most important parameter for determining whether a right-of-way is suitable for BRT investments is the existing level of PT travel demand. That's because current commuters using the specific corridor are most likely to benefit from new BRT investments. Figures 1.7 show the BRT evolution in terms of cities the world.

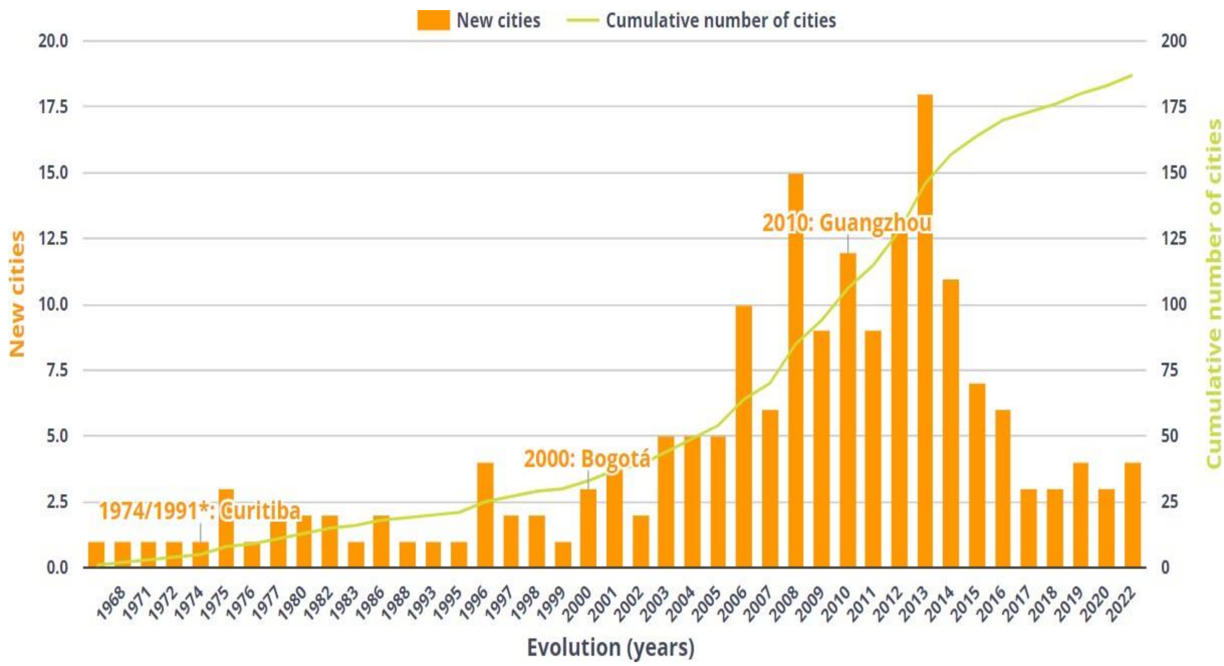



**Figure 1.7** BRT system evolution in terms of cities (Global BRT Data)

A BRT system with high travel demand is likely to benefit more people than a system built on a right-of-way with lower travel demand. The Transit Capacity and Quality of Service Manual (TCQSM), utilized in the United States, recommends a baseline of 1,200 passengers per direction per peak hour (ppdph) for a dedicated BRT lane, reflecting the average usage under mixed traffic scenarios. In developing urban areas with significantly higher public transit ridership, it's probable that a higher minimum benchmark would be set. Some PT planners emphasize that BRT technology cannot handle more than 35,000 ppdph. Therefore, if a corridor is projected to have passenger numbers higher than this, it should be reserved for heavy rail metro (HRM) investments.

The TCQSM and other guides do not offer specific recommendations of this type. However, under certain conditions, these systems can carry more than 35,000 ppdph even with only two lanes of segregated bus lanes per direction. For instance, TransBrasil, which was projected to initiate services at the close of 2018 in Rio de Janeiro, forecasted accommodating as many as 60,000 travelers during peak hours. This projection stems from the extensive utilization of express services, the provision of two lanes in each direction, and the employment of larger BRT vehicles, like articulated buses. A PT modal enables us to introduce a new PT link, potentially at a higher speed than existing links, and identify how many passengers switch. Unlike a modal shift, PT passengers have already decided to use PT. Therefore, they are likely to choose the corridor that offers the quickest trip, even if it's new. Route shift modelling (RSM) requires a comprehensive set of transport data about current conditions, including current ridership and speeds on all PT routes (ITDP, 2007). Figures 1.8 show the BRT evolution in terms of cities lengths the world.

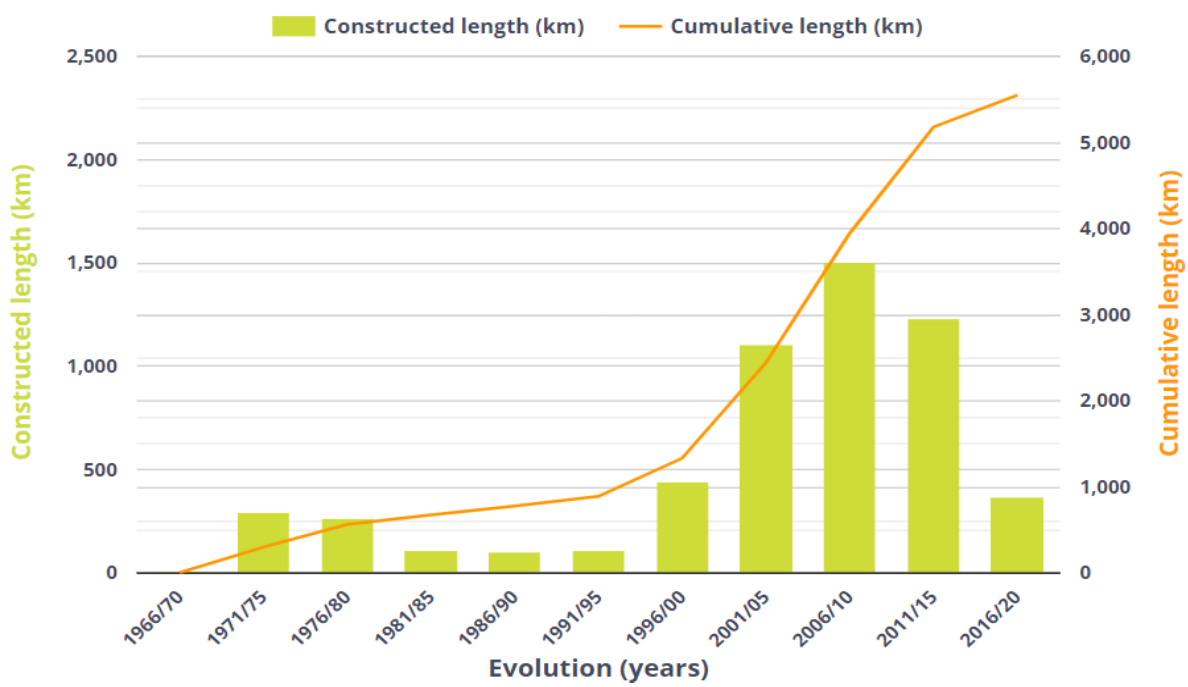



**Figure 1.8:** BRT system evolution in terms of length (Global BRT Data)

## 1.5 Mode Choice

Efficiency and Capacity: Low-Capacity Vehicles, such as motorcycles or small cars, often have low occupancy rates, leading to inefficient use of road space. Promoting public transport encourages multiple passengers to share a single vehicle, maximizing capacity utilization and reducing congestion.

Here are some specific considerations for modal shift from Low-Capacity Vehicles to public transport.

- ❖ Cost Savings: Public transport is generally more cost-effective than operating a low-capacity vehicle. By switching to public transport, individuals can save on fuel costs, maintenance, insurance, and parking expenses associated with owning a personal vehicle.
- ❖ Environmental Benefits: Similar to the previous explanation, the shift from low-capacity vehicles to public transport can help reduce carbon emissions and improve air quality, contributing to a cleaner and more sustainable environment.
- ❖ Infrastructure Development: Enhancing public transport infrastructure to accommodate low-capacity vehicles is essential. This can involve providing designated lanes or spaces for low-capacity vehicles on buses or trains, as well as ensuring accessibility for these vehicles at public transport stations.
- ❖ Integrated Transport Systems: Developing integrated transport systems that seamlessly connect low-capacity vehicles with public transport can be beneficial. This could include integrating bike-sharing programs, carpooling services, or last-mile connectivity options like electric scooters or small shuttles that complement public transport routes.
- ❖ Education and Awareness: Public awareness campaigns can help individuals understand the advantages of using public transport over low-capacity vehicles. Emphasizing the benefits of reduced traffic congestion, improved air quality, and cost savings can encourage people to consider alternative modes of transportation.
- ❖ Incentives and Subsidies: Offering incentives and subsidies to low-capacity vehicle owners who choose public transport can be an effective strategy. This can include discounted public transport passes, reduced fares, or incentives for carpooling or ridesharing.
- ❖ Regulatory Measures: Implementing policies such as congestion pricing, restricted access zones, or toll exemptions for low-capacity vehicles can help encourage a shift towards public transport. These measures can disincentivize the use of low-capacity vehicles in congested areas or during peak hours.

By implementing these strategies, it is possible to encourage a modal shift from low-capacity vehicles to public transport, leading to more efficient and sustainable transportation systems. Figure 1.9 shows the image shift modal to BRT system.

**Figure 1.9** Modal shift to Bus Rapid Transit systems

## 1.6 Impact of Land Use on Transportation and Urban Sustainability

Urban form, the physical characteristics of cities, comprises not only tangible attributes but also intangible features. This complexity is evident, for example, in the concept of density. However, density is a multifaceted concept with interconnected dimensions (Dempsey et al., 2010). It can represent an objective, spatially-based measure of population size in a specific space.

Yet, it can also be interpreted subjectively, a social construct dependent on personal characteristics that can vary from one resident to another (Churchman, 1999). Trafalgar Square in London exhibit a comparatively low residential density, yet its perceived density and feeling of congestion could be notably high (Rapoport, 1975). Density, in the context of urban design, along with elements like housing, transport infrastructure, land use, and planning, plays a pivotal role in influencing the sustainability of a city (Figure 1.10).

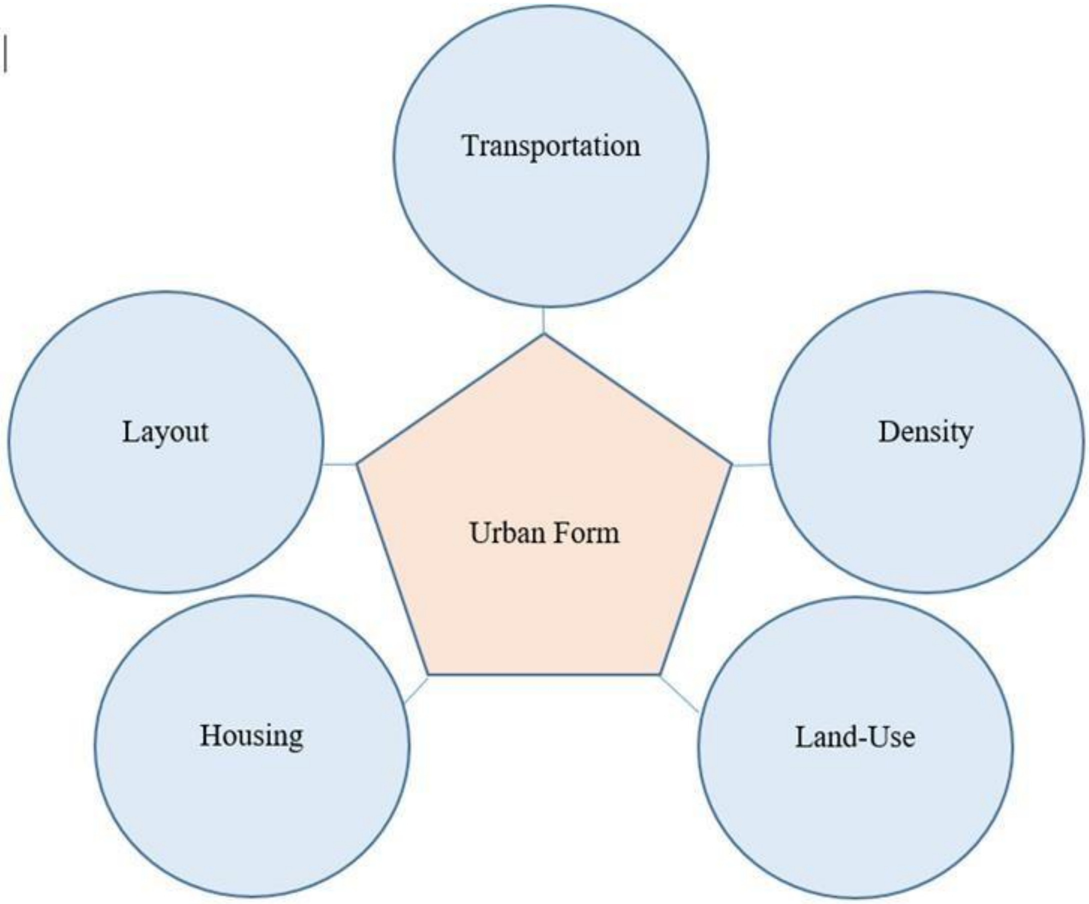



**Figure 1.10** The elements of urban form

Urban form stands as a critical element in urban planning, having the potential to guide a city towards sustainability or, conversely, set it on a course away from sustainability. Experiences have shown that urban sprawl poses a more substantial challenge for cities than urbanization. Urban sprawl, the expanding boundary between cities and rural areas, is driven by various factors, including population growth, socioeconomic characteristics, and policies (Karakayaci, 2016). Studies have linked urban sprawl closely with gross domestic product (GDP), population density, and industrial infrastructure (Guangdong Li, 2019). Understanding urban sprawl is crucial as it has significant ecological, social, and health consequences (Steurer et al., 2020). It has been associated with key problems such as increased dependency on low-capacity vehicles. Urban sprawl, characterized by increased pollution and land resource depletion, can be assessed through indicators like city density, city intensification, mixed area, and road network growth. Among these, city density and mixed land use have a profound influence on travel behaviours. To promote sustainable cities with efficient transportation systems, urban developers and railroad engineer advocate for resolutions such as compact cities, cities of smart, and cities of green. Urban form refers to the physical features that make up urban areas, including the shape, size, density, and configuration of settlements. There are several different types of urban forms, and each reflects the cultural, historical, and economic context of the place in which it developed (Figure1.11). The urban transportation system has an intimate connection with land use.

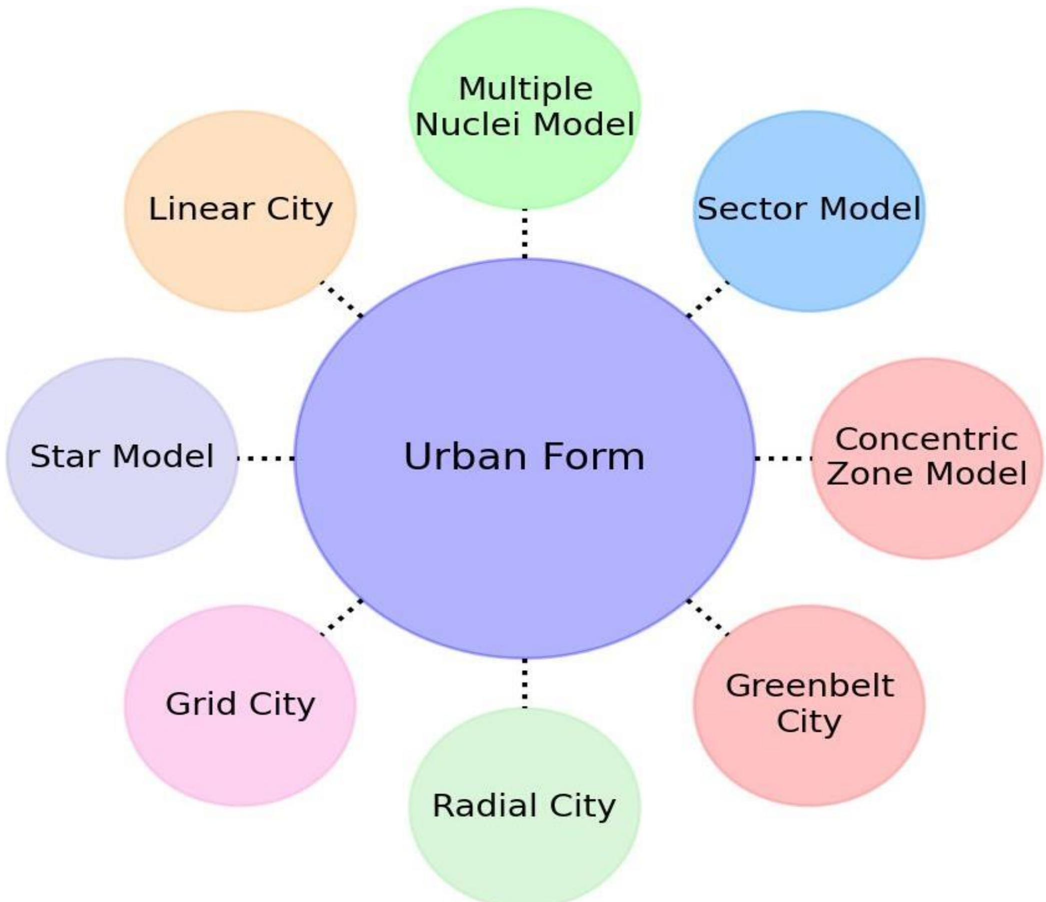



**Figure 1.11** Types of urban form

Different urban forms come with their unique sets of benefits and drawbacks. A comprehensive grasp of these aspects empowers city planners and policymakers to make informed choices regarding the direction of urban development and expansion.

Morimoto (2000) associates this relationship to the interdependence of a chicken and an egg (Figure 1.12)

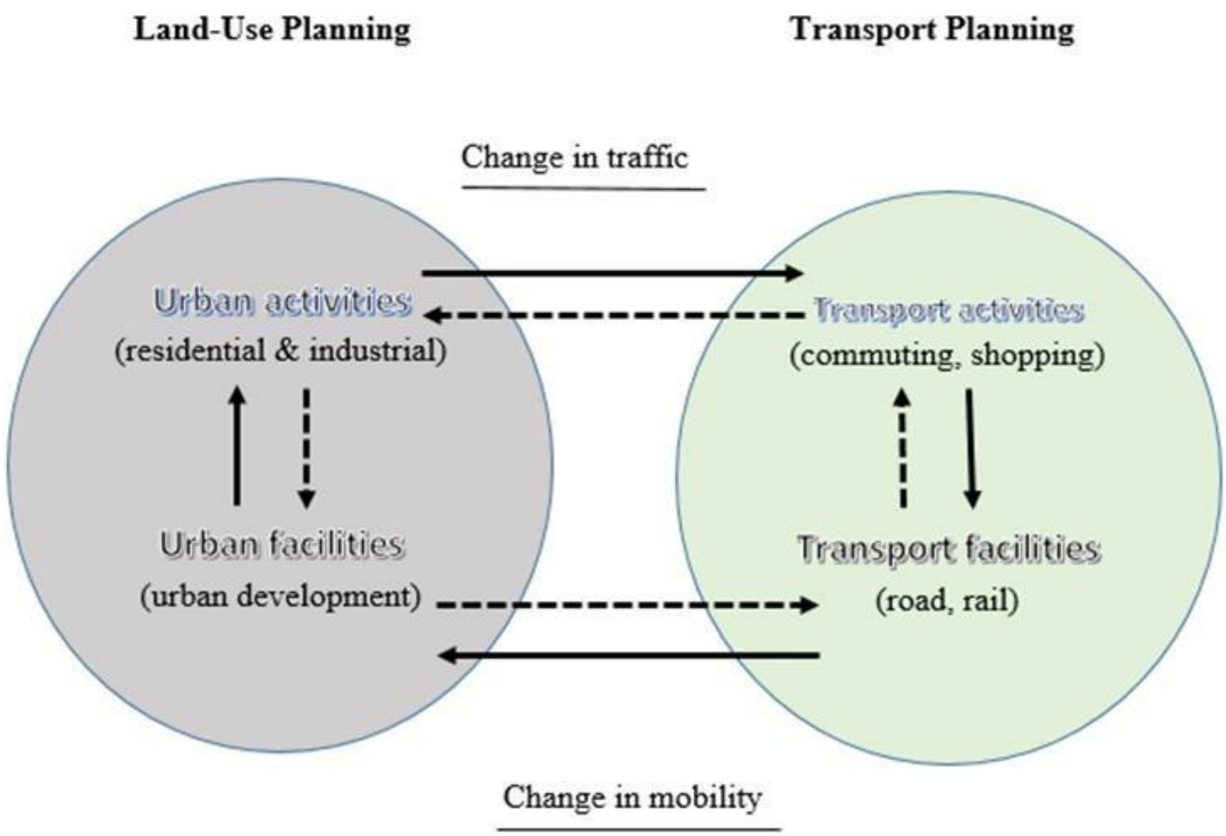



**Figure 1.12** Relationship between Land-Use and transportation

Urban sprawl and compact areas stand as contrasting patterns in urban development. While sprawl denotes widespread, often unplanned, and low-density expansion, compact areas represent dense, well-planned, and efficiently utilized spaces. The interplay between these two concepts significantly influences transportation networks, environmental sustainability, and socio-economic dynamics within cities.

### 1.6.1 Exploring the Basics of Urban Sprawl

Travisi et al. (2010) argued that urban sprawl, often characterized by reduced city densities and the expansion of urban areas, presents a critical urban design challenge. It leads to the loss of green spaces, higher infrastructure and energy costs, increased social segregation, and functional land-use separation. This reinforces the need for travel and intensifies reliance on personal motorized.

In cities characterized by urban sprawl, workplaces, shopping areas, parks, and other facilities are widely separated. As a result, passengers spend more time in vehicles when they travel from one locationto another. On the other hand, in a compact city, the demand for motorized systems is reduced, andresidents can often walk or bike to shops, work, and recreational areas. A high level of compactnessenhances transit systems, reduces travel distances and time, and decreases emissions. From the above explanation, it can be inferred that there is a strong correlation between urban sprawl and travel behaviour. Particularly, population density (Figure 1.14) has a profound impact on the transportation system.

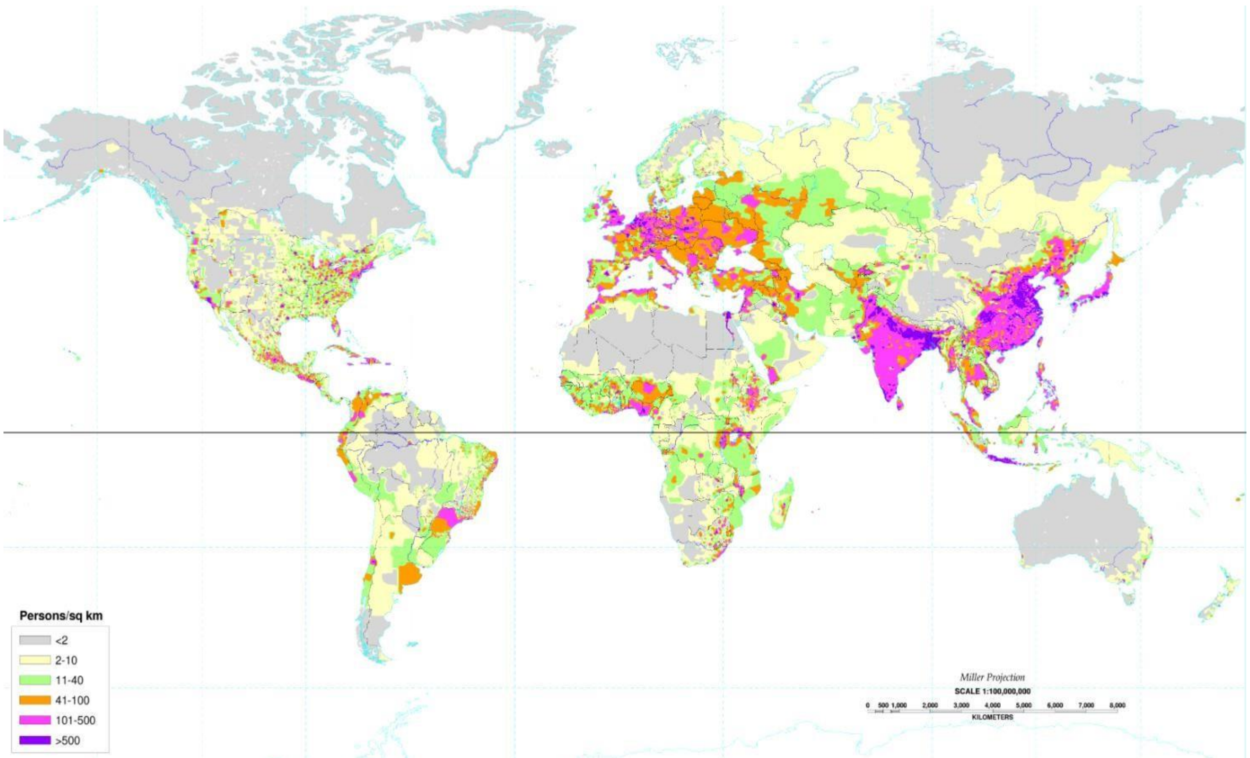



**Figure 1.13 Population** density across the world (Wikimedia Commons 1994)

### 1.6.2 Principles of the Compact City

The concept of the compact city stands as a fundamental idea in advancing the development of sustainable urban areas on a global scale. It mitigates urban sprawl and promotes sustainability, protecting green and agricultural areas while reducing transportation needs. Therefore, planners and engineers focus on densification, decreasing car dependency, promoting mixed use, and preserving open space through the concept of the compact city. Numerous recent reports and policy documents suggest that the compact city positively impacts resource efficiency, economic vitality, The compact city is designed to make optimal use of existing land resources and infrastructure, as well as to reduce the use of vehicles as public transport becomes more prevalent (Arbury J 2005). Fundamental aspects such as mixed land-use, energy performance, efficient urban infrastructure, efficient public transport, accessibility, encouragement of walking, high density, social interaction, encouragement of cycling, reduced car dependency, decreased pollution, short distances, and provision of services and facilities are considered the main elements of a compact city (Rogatka et al., 2015). Based on the following study the elements of compact city are defined in Table 1.2.

**Table 1.2** Compact city elements and details

| # | Element | Definition |
|---|---|---|
| **1** | Mixed-use | Mixed use is a type of urban development that blends multiple uses, such as residential, commercial, cultural, institutional, or entertainment, into one space, where those functions are to some degree physically and functionally integrated, and that provides pedestrian connections. |
| **2** | Short distance | Provide walking and cycling. |
| **3** | Reduced pollution | Renewable sources decrease emissions. |
| **4** | Car dependency | In the concept of compact cities, car dependency is minimized because these areas promote mixed-use development, allowing residents to live, work, and access amenities within a short distance. |
| **5** | Encouraging cycling | Refers to initiatives and measures taken to promote the use of bicycles as a mode of transportation. These efforts aim to create a supportive environment for cycling, which includes developing infrastructure such as bike lanes and parking facilities. |
| **6** | Social interaction | These suggest well-managed city infrastructure; for instance, green places, where residences from different socio-economic levels can meet and communicate. |
| **7** | High density | High density refers to areas that are developed to accommodate a large number of people or activities in a relatively small space. |
| **8** | Accessibility | This element provides a minimum barrier to public spaces. |

## 1.7 Scope of the Work

The scope of this thesis encompasses a comprehensive analysis of possibility of BRT systems as a sustainable transportation solution in urban environments, particularly focusing on Kabul and Jalalabad, Afghanistan. This study investigates the potential of BRT to influence urban mobility and mode choice among residents, considering the challenges posed by urban sprawl, traffic congestion, and the segregation between land use and transportation. By evaluating travel demand, modal shift preferences, and the impact of urban form on transportation sustainability, the thesis aims to provide empirical insights into the feasibility and implications of implementing BRT systems.

## 1.8 Need for the Study

Urban sprawl is an aspect that requires further consideration from transportation planners and engineers, as it directly impacts transportation systems and is generally undesirable. This process raises complex issues concerning transport, demographics, economy, environment, and decision-making factors. Transportation emerges as a central factor requiring attention, given the rapid expansion of distances between functional urban regions. Local governments face challenges in keeping pace with the swift urban growth. They aim to ensure the growth is sustainable and does not harm the environment or the community. Additionally, congestion, extended commutes, the sprawl of cities, and pollution stand out as majordetrimental issues in urban areas worldwide, with a particularly significant impact on millions of city dwellers, especially in developing nations. Longer distances connecting residential zones andwork or school areas are the major causes of increased personal mobility. In such cases, some citiesworldwide experience an abnormal urban sprawl taking the form of peri-urbanization (Iațu et al., 2012; Liu et al., 2010). Traffic congestion is directly related to overloading in an urban area. The interaction between landuse, transportation choices, and infrastructure significantly influences traffic flow. Factors like rising travel demand, freight transport, and the absence of efficient BRT systems contribute to traffic congestion, primarily caused by commuter journeys. Recent evidence shows that moderndrivers spend three times more time in traffic than a few decades ago (Rodrigue, 2020). The prevalence of low-capacity vehicles increases traffic volume, leading to overcrowding, air pollution, inefficient fuel use, and longer travel times, negatively impacting urban quality of life. Growing populations, ongoing road construction, and increased distances between residences andworkplaces extend congestion and commute times. Surprisingly, expanding road capacity does notalways reduce travel times; it can sometimes worsen congestion by accommodating more vehicles and increasing vehicle-miles-travelled (VMT).

While some studies have analysed the factors that influence BRT corridor selection, there is a need for more empirical research that uses four-step methods to identify the most appropriate corridors for BRT systems in urban areas with high travel demand. In prior research, the focus was primarily on analysing the shift from private cars and motorcycles to transit systems. However, the shift from rickshaws, share-taxis, and cars to BRT systems has been overlooked, despite factors like waiting time, station type, corridor type, air conditioning availability, station distance, travel time, and travel cost being influential. While previous studies have explored the connection between travel behaviour and mixed land use/density, a research gap exists in understanding how density influences mode choice in various traffic zones. This gap includes examining residential, employment, student, and road density as contributing factors.

As suggested, the abstract has been modified to incorporate the key scientific contribution: The thesis aims to explore the impact of Bus Rapid Transit (BRT) systems on urban mobility, specifically examining how BRT influences the mode choice among urban residents. It contributes to the body of knowledge by providing empirical evidence on the efficacy of BRT systems in encouraging a modal shift from private vehicles to public transport, and examines the relationship between the built environment and mode choice.

Considering local circumstances, Kabul and Jalalabad cities confront these challenges; hence, comprehensive studies are crucial to address and minimize these issues. In the analysis and modeling of Kabul's urbanization and transportation systems, the geographic unit used is the municipal area of Kabul, which spans 1,025 km² and comprises 22 districts. In order to achieve accurate results, the city was divided into 213 traffic zones. Hence, traffic zone is the unit for analysis.

For Jalalabad city, disaggregate Stated Preference (SP) data were collected through a survey along the PT routes to analyze the mode shift from the current modes to the proposed BRT system.

### 1.9 Objective of the Study

Considering the provided background and acknowledging the significance of research concerning urban sprawl, its connection with travel behaviours, and the implementation of the BRT system, the study's objectives have been established. These objectives include:

1) To examine the feasibility of implementing a Bus Rapid Transit system based on travel demand;

2) To evaluate the potential for a mode shift from low-capacity vehicles to a Bus Rapid Transit system;
3) To assess the relationship in terms of the built environment and mode choice relationship

### 1.10 Report Organization

A detailed literature review of compact city , urban analysis, travel demand , and mode shift is concisely outlined in Chapter 2. Chapter 3 demonstrates the application of the Four-Step method in travel demand modelling. This model development incorporates influential factors (or independent variables) such as population, employment, and car ownership. The corridor for a proposed BRT system is identified, primarily based on areas with high travel demand. Chapter 4 of the study employs the Ordinal Logistic Regression (OLR) model to gain insights into the behaviours of current mode users, specifically those who use automobiles, shared taxis, and private cars. This analysis is based on Stated Preference (SP) data related to the proposed BRT system. Various attributes of the BRT system, including factors such as travel time, travel cost, waiting time, walking distance to the station, station-to-station distance, corridor type, station type, availability of air conditioning, trip purpose, possession of a driving license, car ownership, gender, and age, were taken into account. In the SP survey, respondents were presented with 16 different BRT scenarios designed for a specific corridor spanning 10 kilometres. They were then asked to indicate their level of satisfaction using a ranking method. Chapter 5 investigates urban sprawl, focusing on land use and population density. The compactnessof various city zones is assessed. Transportation choices in these zones are then examined based on their compactness. The goal is to determine how city layout influences residents' transportationdecisions. Chapter 6 serves as the culmination of this study, offering a concise summary of its key findings, conclusions drawn from the research. These recommendations stem from the insights gleaned from the study's exploration of the interplay between urban density and travel behaviours and the introduction of a bus rapid transit system in densely populated areas.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 General

The chapter provides a crucial examination of current literature concerning BRT systems, focusing on performance measures, the transition from low to high-capacity transit, and the relationship between land use and transportation choices. Through analyzing these topics, the chapter seeks to clarify the present knowledge base, pinpoint gaps in existing studies, and define the direction and scope of the upcoming study. This method ensures a solid foundation, guiding further research questions and dialogues in a strong scholarly context.

## 2.2 Bus Rapid Transit System

Numerous studies have been conducted on BRT systems, revealing their transformative impact on urban mobility and environment. Previous experiences from various provinces and cities underscore the capability of BRTs to enhance public transit efficiency and foster sustainable development. Literature often emphasizes aspects like system performance, route optimization, and passenger experience while scrutinizing diverse global models to derive viable insights. These studies lay a groundwork, enabling cities to learn, adapt, and implement BRT systems effectively, tailoring them to local contexts and needs.

### 2.2.1 Bus Rapid Transit Performance and Influencing Factors in Route Choice

Prior learnings from BRT implementations highlight the crucial role of thorough planning and community involvement. Essential elements like socio-economic factors, urban structure, and political support significantly influence the effectiveness and longevity of BRT systems across different global contexts. Satiennam et al. (2006) introduced policies to promote BRT adoption in developing regions. One policy advocated integrating Light Commercial Vehicles (LCVs) as feeder services with dedicated BRT lanes to meet demand. These policies were evaluated using travel demand and emission models applied to Bangkok's BRT plan, showing they could enhance ridership mobility and reduce air pollution. The study suggested extending these findings to provide strategic recommendations for implementing BRT systems in other developing Asian urban areas. Currie et al. (2006) conducted a study to assess the performance of BRT systems in Australia. The study provides insights into the primary BRT systems operating in Adelaide, Brisbane, and

Sydney, detailing their structure, services, and developmental characteristics. The study also examines how these BRT systems have influenced aspects such as patronage, market dynamics, services, and the overall development of the respective cities in which they operate. Furthermore, these systems are also reviewed in terms of implementation and operation. Finally, the article concluded that four BRT systems have been improved with various features and appearance. All have obtained attractive ridership effects and are well-valued by passengers, and it is predicted that within the next two years, Australian metro bus systems will grow by about 50%. Vaishali et al. (2007) investigated the influence of exclusive BRT lanes compared to conventional mixed traffic lanes on commuter mobility and traffic flow. The findings revealed a positive impact of the BRT on mobility, as demonstrated by examining multiple traffic factorsin the corridor. The average speed and volume of traffic in the observed BRT lane doubled compared to the previous state. Simultaneously, travel time and delay duration were substantially reduced in the new BRT corridor compared to the prior state. Efficiency in fuel consumption improved across all transportation modes. The study identified cars and two- wheelers as the primary contributors to congestion, pollution, and excessive fuel use. Finally, the research underscored the immediate need for a BRT system as a viable solution to tackle transportation congestion and implement pollution control policies.

Abdelghany et al. (2007) introduced a dynamic traffic assignment-simulation analysis concept to enhance the evaluation and planning of BRT services in urban transport corridors.
The model outlines various features associated with BRT services, such as dedicated rights-of-way or corridors, limited-station service, traffic signal prioritization at congested intersections, and upgraded bus stations to decrease commuter boarding times. Consequently, a set of simulation tests is carried out using the model to investigate the impact of introducing a potential BRT system in Knoxville, Tennessee. In these tests, the various operational features of the BRT system are evaluated in terms of their potential impact on public transit ridership. The results highlight the benefits of the BRT system for enhancing transit ridership and improving overall system performance.

Cain et al. (2007) focused on the multiple capabilities of BRT systems, using the TransMilenio as an illustrative example, and assessed the applicability of these capabilities to BRT operations in US cities. The research involves a series of observations on passenger capacity, capital cost-effectiveness, achievement of modal shift goals, urban area redevelopment, and marketing. The study concludes by addressing various issues concerning the implementation of BRT systems in US cities. The most important lesson gleaned from the operation of TransMilenio in Bogotá is that BRT systems can significantly contribute to broader objectives, such as efficient mobility and urban renewal, when incorporated as part of an integrated set of policies. Committing to developing a network of BRT routes enables a city to enhance mobility and urban renewal benefits from a single corridor to a citywide level. The relatively modest capital costs that facilitated this transformation within a relatively short timeframe could also be appealing to US cities.

Hidalgo et al. (2008) conducted a study to illustrate how Bogotá has implemented such strategies, specifically with the TransMilenio BRT system. Their focus was on three elements: i.e. coverage,  accommodation for non-motorized amenities; and improving working conditions for BRT operators. They analysed how these elements have been considered in planning the TransMilenio BRT system and the impacts realized during its implementation in Bogotá. The findings indicate that the BRT system enhances accessibility from suburban areas to workplaces, includes provisions for non-motorized facilities, and improves working conditions by formalising deregulated services. Over time, usage by low-income individuals has increased due to the development of feeder roads. These individuals benefit from significant time savings and reduced travel costs. Furthermore, there has been a reduction in accidents and air pollution.

Quan Li et al. (2009) proposed an optimization model to address the synchronization aspects of BRT vehicles to minimize overall travel and dwell time. The computational results illustratethat a BRT system with a single exclusive lane delivers a total travel time similar to that of a BRT system with double exclusive lanes, provided the headway does not exceed 20 minutes. Moreover, to consider potential delays at intersections, a straightforward speed control algorithm is implemented to adjust the BRT's pace in real time if the bus service experiences significant delays. A microscopic simulation based on VISSIM is executed to examine the effects of the BRT system on other modes of travel and the effectiveness of the speed control. The simulation results indicate that the speed control effectively mitigates intersection delays, and the speed control barely impacts other modes of travel.

Maparu et al. (2010) conducted a study that focused on creating a methodology to determine the right-of-way for introducing a metro bus system in urban areas, with Kolkata as a specific case study. The study aimed to address escalating traffic congestion, the rise in private vehicle numbers, declining road and transportation infrastructure, and the deteriorating level of service (LOS) in the public transport system within the city. The study's methodology combined a current travel demand assessment and a feasibility investigation concerning transportation and road infrastructure features for determining and phasing the BRT right-of-way. This association of feasibility constraints enables planners and decision-makers to make informed decisions regarding implementing BRT systems in Indian cities.

Gahlot et al. (2012) discussed a model for the practical determination of BRT right-of-way for Jaipur city in India based on a Geographic Information System (GIS) environment. The model aims to select the BRT right-of-way according to the spatial distribution of public transport trips in the urban area studied, projected into the future. The study utilised demographic data, public transport trips, and land-use characteristics of the area to identify the best passenger-oriented BRT right-of-way. This approach includes two models; the first is for BRT travel demand and forecasting, and the second is for determining the BRT right-of-way based on predefined conditions. The model generates graphical, GIS-based maps as outputs, enhancing understanding of public transport travel demand and informing policy-making for city planners. This procedure could be used effectively for BRT system planning in any urban area of similar size within the Indian context.

Wirasinghe et al. (2013) analysed various aspects of BRT features. The study provided an overview of the components of BRT systems: right-of-way, buses, stops, operational control, fare collection, and user information rules. The research elucidated how these elements enable BRT systems to achieve speed, capacity, safety, convenience, and characteristics that distinguish them from traditional bus services. Each mature BRT system is unique and depends on the design and integration of these fundamental components. The study also extensively evaluated environmental, social, and financial impacts, passenger perceptions, and modal shift towards the BRT system. With regional land-use and transportation strategies that promote high-density and mixed-use development, BRT systems have been shown to attract potential improvements around bus stations and along its right-of-way, increasing land values and promoting sustainable development. As the analysis reveals, infrastructure costs fluctuate greatly depending on land acquisition values, station design, level of traffic separation, technological features, and labour costs. As a result, BRT capital costs cannot be generalized and must be carefully adapted based on variations in input costs that differ from location to location. The study also addressed obstacles to BRT that impede significant success in customer satisfaction and ridership gains, citing specific case studies. The comprehensive review of BRT systems suggests that, in some instances, they perform comparably to more advanced public transit systems while maintaining unique characteristics that distinguish them.

Hidalgo et al. (2013) present the main features, costs, and impacts of TransMilenio in Bogotá, Colombia, a mass transit system utilising BRT lanes and supply services. This study conducted a pre-profit cost analysis, incorporating financial evaluations of significant impacts on travel time, travel costs, and additional benefits such as improved road safety and air quality. Effects on crime rates, land prices, employment, and taxation were also reported. The results are promising and robust; however, it is essential to note that user satisfaction has declined, indicating an urgent need for service improvements. The paper also includes an initial assessment of the anticipated expansion using current costs, suggesting a need to reduce construction costs. The findings highlight the potential of BRT, and the evaluation method could apply to other transportation projects.

A primary investigation of BRT corridor options was completed for this study. The study proposes six alternative routes to connect downtown Portland Valley and Damascus. A multivariate corridor evaluation was conducted for each alternative, considering local connectivity, regional patronage, operational running, travel time, travel distance, corridor and state feasibility, environmental costs, and capital costs. Proposals for optimal stop locations along the selected corridor were also developed. This investigation aims to aid Tri-Met in the planning, designing, and implementing a BRT system in the region. The findings suggest that the Powell/Interstate 205/Foster alignment is suitable for a BRT system. Additionally, the results indicate that implementing BRT can positively impact land use and lead to increased transit ridership in the area (Pahs et al. 2002).

Deng et al. (2013) studied the performance and impacts of the BRT system in Beijing, the first of its kind in China. They examined the role of Intelligent Transportation System (ITS) technology in affecting operational efficiency, technical performance, and cost-related matters of the BRT. The study particularly highlighted the effects of BRT on altering travel behaviour, influencing the traffic environment, and generating property development. Despite the presence of some ongoing challenges, the initial performance of BRT indicated its potential as a significant approach to promoting sustainable mobility. Moreover, the study illuminated the significance of integrated planning and policy-making in optimizing the functionality of BRT systems. It underscored the need for ongoing evaluation and adjustments to ensure that these systems can effectively adapt to evolving urban transport demands and provide reliable, efficient, and sustainable mobility solutions. It also suggested that the successful implementation of BRT in Beijing could serve as an encouraging model for other cities seeking to improve their public transportation infrastructure.

In 2014, Maeso and his team conducted a study with a global perspective on BRT systems, aiming to provide a practical comparison that could lead to significant findings. The research undertook a comprehensive qualitative and quantitative analysis of current operational systems relative to the countries' development level in which they function. The goal was to identify the critical elements for the success of such transport systems, considering both its management and the comfort of passengers. The study contrasted outcomes and interpretations among BRT systems based on their geographical location, providing substantial insights. The findings suggest a clear division in BRT systems: some urban areas feature advanced technology and commercial speed (such as in European, Australian, and American BRT systems), while others emphasise service development, ridership, routing, and impact on the population. Recognizing the BRT within urban mobility is vital, given that the BRT system must compete with other forms of urban transportation.

In a study conducted by Abbasi et al.( 2019), they examined the first line of the BRT system in Tehran to increase the effectiveness of this mode of Public Transport (PT) in the city under study. The team employed Aimsun software to simulate the implementation of segregated bus lanes, lowering bus headways, applying actuated traffic signals, and upgrading city bus stops across ten scenarios. Non-linear regression models were utilised to forecast reductions in travel times and fuel usage. The findings suggest that transforming shared lanes into segregated ones could reduce travel times by 2.95%, CO emissions by 9%, PM emissions by 1.13%, NOx emissions by 3.45%, and fuel consumption by 5.3% per km. Additionally, substituting the existing signalization along the corridor with fixed signals led to a decrease in travel times by 6.31%, CO emissions by 25.9%, PM emissions by 3.42%, NOx emissions by 6.2%, and fuel use by 5.26%. An economic angle was also adopted to examine the recommended scenarios, weighing the costs of implementing each scenario against the benefits of reduced travel time, pollution, and fuel usage. It was found that fully dedicated BRT lanes yielded the highest reduction in annual costs, with Scenario 4 saving the most at $83 million and Scenario 9 saving the least at $5 million. The study concluded that the BRT system has significant economic and environmental implications.

Jalal et al. (2015) utilized travel demand modelling in Kabul city to identify significant factors affecting travel behaviours. The study found that population, employment, travel time, and travel distance play crucial roles in trip generation, trip distribution, and mode choice. Furthermore, they concluded that the introduction of a mass rapid transit system in Kabul could alleviate congestion and potentially contribute to reducing pollution. In addition to these findings, the study also emphasized the importance of understanding the interplay of these factors in shaping transportation strategies. By recognizing the implications of these influential elements, policymakers could better design and implement effective mass transit systems, ultimately enhancing the overall commuting experience and improving environmental conditions in Kabul.

Callaghan et al. (2018). provided an initial evaluation of the Orange Line BRT system in Los Angeles, one of the most robust full-featured BRT systems in the United States. Additionally, they compared this BRT system to the Gold Line Light Rail Transit (LRT) and a rapid bus system with some BRT features. This evaluation was based on performance, cost, and operational data from the Orange Line BRT system during its first year of operation. The study found that the Orange Line BRT system exceeded ridership projections, reduced travel times, alleviated congestion, and successfully attracted commuters away from their cars. Furthermore, this system performed better than the Gold Line system, which incurred significantly higher costs but carried fewer passengers. The rapid bus system, with limited BRT features, appeared to offer some advantages in terms of cost but resulted in longer travel times and less appeal. The performance of the Orange Line BRT system also provides valuable insights for future BRT planning.

Pulugurtha, S. S., et al. (2022). examined the link between transit service reliability indicators and ridership, analyzing how the road network, demographic, socioeconomic, and land use characteristics influence transit reliability. The research utilized bus arrival/departure and ridership data from the Charlotte Area Transit System (CATS), focusing on bus stops. Environmental variables were assessed within 0.25-mile and 0.50-mile radii around these stops. Using Pearson correlation analysis, the study explored the relationship between these variables and transit service reliability. Findings indicate that bus transit reliability significantly affects ridership and is shaped by the surrounding road network, demographic, socioeconomic, and land use factors. These insights aid public transit agencies in optimizing resource allocation, planninyg, and delivering equitable services to all users.

### 2.3 Insights into Modal Shifts

Past studies illuminate varied success stories and challenges encountered, spotlighting critical factors like urban design, policy-making, and socio-economic considerations that drive modal shifts towards BRTs. This underscores a need to further examine and understand the detariled factors driving these transportation shifts within distinct urban contexts.

### 2.3.1 Modal Shift from Low-Capacity Vehicles to Mass Rapid Transit Systems

The study assesses past experiences related to modal shifts from low-capacity transport to BRT systems. It explores various facets of implementing BRTs, focusing on historical data and outcomes from different geographical contexts.

Sonu Mathew and Srinivas S. Pulugurtha (2022) discuss the potential of light rail transit (LRT) systems to alleviate traffic congestion and enhance travel time reliability. It highlights various studies on the impact of LRT on traffic flow, transit-oriented development, and travel time reliability measures. The review also emphasizes the need for comprehensive analysis to understand the LRT’s effect on travel times and reliability. The research aims to fill these gaps by assessing the LRT system's impact on travel time reliability, particularly on links adjacent to the LRT corridor. This work contributes to a better understanding of how LRT systems influence urban traffic dynamics and aids in transit planning and decision-making.

Wang et al (2011). collected data via surveys from passengers across six BRT corridors in China. This data encompassed demographic and socioeconomic characteristics of passengers, including gender and age, as well as travel characteristics such as travel distance, purpose, time saved on trips, travel cost, and trip frequencies during a week, by employing a Binary Logistic Analysis (BLA) to understand the significant variables influencing the shift from cars, conventional buses, and non-motorized transport to the BRT systems. Their results revealed that traveller characteristics and travel features played statistically significant roles in this mode shift towards the BRT system. Moreover, the study underscored the importance of acknowledging the diverse nature of ridership and travel preferences during the BRT system's implementation. This highlights the need for tailored strategies that consider commuters' varied needs and behaviours to encourage wider acceptance and usage of BRT systems.

Ben-Akiva (2002) embarked on a study to discern if evidence exists to support a preference for rail systems over BRT systems. They implemented a mode choice model, utilizing both revealed preference and stated preference data collected through a survey.

Their findings revealed no substantial evidence to support the preference for rail systems over BRT systems, assuming equal quantifiable service features. In other words, when variables such as travel time and cost are held constant for both systems, there is no apparent preference for the rail system. This emphasizes the competitive potential of BRT systems when matched against rail systems in terms of service quality and cost-effectiveness.

Ingvardson et al. (2017) conducted a study addressing the comparative gap in MRT systems through a comprehensive literature review encompassing 86 cities worldwide. This research covered many transit systems, including BRT, Light Rail Transit (LRT), metro, and heavy rail transit systems. The research was organized in two main phases. The first phase investigated these systems' effects on travel time, mode shifts, and ridership. The second phase explored indirect strategies, specifically their effects on property values. In conclusion, they deduced that BRT systems have the potential to attract a significant number of passengers, mainly when substantial reductions in travel time are achieved. This study underscores the high-performance capabilities of BRT systems and their substantial influence on urban transit efficiency.

Alvinsyah et al. (2005) conducted a study to distinguish the elements influencing mode shifts between public transit systems and low-capacity vehicles. The research data encompassed socioeconomic attributes such as family structure, age, gender, income, and travel characteristics, including travel time, travel cost, and the value of time. They utilized a binomial logit model and a Stated Preference (SP) survey to scrutinise passengers' attitudes towards a proposed public transport system. Their exploration unearthed variations in individuals' attitudes and the likelihood of their opting for a more convenient service. The findings from this study underline the importance of considering user perspectives and travel characteristics when planning public transportation enhancements.

Bajracharya (2008) undertook a study in Ahmedabad, India, applying a modal shift model to assess the existing public transportation and the proposed BRT system. The research incorporated a Stated Preference (SP) survey conducted within the study area to explore passengers' readiness to transition from the current low-capacity public transport to the proposed BRT system. The findings underscored that socioeconomic attributes and travel behaviour significantly influenced the potential mode shift from the current transportation options to the proposed BRT system. Such results highlight the criticality of understanding the user's socioeconomic background and travel habits when implementing new public transportation systems, such as BRT, to ensure higher adoption rates.

Ridership plays a crucial role in the success of a BRT system. Before implementing such a system, an assessment of the potential modal shift is often carried out to promote sustainable transit solutions (Ko et al., 2019). A modal shift becomes viable when one mode of transport presents considerable advantages over other transportation options, encouraging a change in travellers' decision-making habits (Ahanchian et al., 2019). These advantages can be linked to reduced travel time, cost-effectiveness, enhanced comfort, or a more environmentally friendly mode of transport.

A study by Satiennam et al. (2016) investigated the BRT system's appeal to passengers who usually use private cars or motorcycles. In their study, they developed three BRT system scenarios and proposed them to car and motorcycle users through a survey conducted in Khon Kaen City, Thailand. A modal split model was utilized for this investigation, employing the Stated Preference (SP) method. The findings indicated that travel time, cost, gender, and age were the most influential parameters. Moreover, the BRT system demonstrated a higher capacity to draw users from the pool of motorcycle users than car users. This suggests a potential for significant shifts in modal preference towards the BRT system, particularly among motorcycle users.

## 2.4 Urban Area and Urban Transportation

Various studies have acknowledged the strategic connection between the transportation network and urban planning. However, insufficient empirical evidence has been found to regulate this aspect through an integrated approach towards spatial transport development. This calls for further research and initiatives to effectively intertwine transportation planning with urban development, ultimately leading to more sustainable and efficient cities.

### 2.4.1 Relationship Between Land Use and Mode Choice

Past research underscores how land use patterns influence transportation choices, revealing that strategic urban development can steer inhabitants towards more sustainable travel options.

Handy et al. (1992) aimed to investigate the relationship between land use characteristics and mode choice, explicitly focusing on non-work trips and accessibility in four locations within San Francisco. The research found that several accessibility parameters were significant at the individual level. However, the study concluded that the measurements had limited explanatory power in understanding mode choice.

Ewing et al. (1994) conducted a study using trip diary data from Palm Beach City, Florida. The researchers examined various factors, including residential and employment density, jobs-home ratios, accessibility, and the presence of multifamily units. The study investigated travel time, mode choice, and trip frequencies.

Kitamura et al. (1994) conducted a study in five urban areas in San Francisco. They collected data regarding travel features, population, attitudes, built-form features, and household socioeconomic characteristics. Finally, the parameters were modelled. The results reveal that socio-demographic factors and attitudes are more significant than land-use characteristics.

Handy (1996) utilized trip diary data from two cities in the Bay Area to explore the effects of block density (measured as blocks per square mile), the number of commercial establishments per capita, and access to the city centre on non-work travel patterns. The author found that areas with higher levels of accessibility exhibited a significantly higher frequency of non-work trips. Additionally, the comparison between traditional and suburban neighbourhoods revealed that land-use characteristics outweighed the impacts of socioeconomic factors on travel behaviour.

Mane, A. S., & Pulugurtha, S. S. (2020) explores the impact of land use and network characteristics on travel time for road links in Charlotte, North Carolina. Utilizing data from 259 links, the study examines 35 different land use types within varying proximities (0.5 to 3 miles) to these links. It assesses spatial dependencies by analyzing the land use within these buffer zones and the network features of adjacent roads. Two modeling approaches were employed: one using all predictor variables and another using non-correlated predictors based on Pearson correlation coefficients. Additionally, the study categorized links by area type (central business district, CBD fringe/other business districts, and urban areas) and speed limit (35-40 mph, 45-50 mph, and over 50 mph) to gauge their effects on travel time. The gamma distribution model with a log-link was found to be the most suitable for the data. Results indicated varying contributions of land use and network characteristics to travel time based on the buffer size, with a 1-mile radius being optimal for capturing land use effects on travel time. This variation was also influenced by the link's location and speed limit. This study aids in refining land use and transportation planning by identifying key factors influencing travel time at different spatial scales and conditions.

Lawrence et al. (1994) aimed to determine if there was a correlation between urban structure and mode of transportation, if this correlation persisted after controlling for non-urban form variables, if this relationship was linear or non-linear, and if a strong association existed between transportation choice and urban structure. They created a database with a wide array of variables and applied a correlational research design where transportation choice was compared among census tracts with varying degrees of density and mixed-use. Their findings revealed that density and mixed-use were associated with transportation choice, even when controlling for non-urban form variables. This was held for both work and shopping trips. Moreover, the study uncovered a non-linear relationship between population, employment density and transportation choice for single-occupancy vehicles (SOVs), public transportation, and walking, whether for work or shopping trips. As density and mixed-use increased, so did public transport and walking, while SOV usage decreased. The conclusions drawn from this research indicate that estimating urban structure at both the origin and destination of trips provides a better prediction of travel choices than considering each endpoint individually. Also, enhancing the degree of land-use mix at both the trip origins and destinations correlated with decreased SOV use and increased transit and walking.

Schimek (1996) conducted a study to understand whether population density influences the number of household car travels in the US. The 1990 Nationwide Personal Transportation Survey (NPTS) collected the data. This article applied a simplified land use-transport system model and considered a specific density neighbourhood. Households chose the number of vehicles to own and then determined the number of motor vehicle journeys or the overall vehicle journey distance. The research found that a 10% improvement in density resulted in only a 0.7% reduction in household car travel.

Crane (1996b) evaluated the relationship between travel demand and land-use characteristics. The author developed a model to identify this context's significant and influential land-use factors. The study's results demonstrated that various land-use factors have distinct impacts on trip time and length.

Cervero et al. (1997) researched to investigate the impacts of land-use characteristics on mode choice. The study revealed that land-use characteristics influence travel behaviour and vehicle miles travelled (VMT). However, the study emphasized that socio-demographic features play a more significant role in mode choice than land-use features.

Kain et al. (1977) analysed the impact of urban form patterns, density, job location, and car ownership on mode choice in over a hundred metropolitan areas. The study employed travel demand modelling techniques to examine these relationships. The analysis results revealed that urban densities and car ownership rates significantly influence mode choice.

Cervero et al. (1997) investigated the influence of urban form on travel demand, focusing on three principal dimensions: density, diversity, and design. They evaluated how these factors affected the trip rates and modal choices of residents in San Francisco. The study utilized data from 1990, including travel data and land-use records obtained from U.S. Census data, local inventories, and area surveys. The study specifically focused on estimating the relationship between the built environment's characteristics and variations in vehicle miles travelled per household and mode choice, particularly for non-work trips. Factor analysis was used to combine parameters linearly into the urban form's density and design dimensions. The findings revealed that density, urban diversity, and design generally decrease trip rates and encourage non-motorized travel statistically significantly. This suggests that thoughtful urban planning can influence travel behaviours, promoting sustainable transport methods and potentially reducing congestion and carbon emissions.

Mukoko, K.K., & Pulugurtha, S.S. (2019) collected data on network, land use, and demographic factors at 119 locations to analyze their impact on crash frequency. Using 99 locations for model development and 20 for validation, six models were developed with a Negative Binomial distribution to handle over-dispersion in the data. Findings indicated a higher likelihood of crashes on roads lacking bicycle lanes, equipped with traffic lights, having a 45 mph speed limit, and situated in commercial, research, institutional, densely populated residential, or heavy industrial areas. Moreover, using Moran's Index revealed weak to no spatial correlation in crash residuals, suggesting that crash occurrences are more closely related to specific site characteristics than to general spatial patterns.

Kitamura et al. (1997) utilized the same dataset and conducted further analysis. The findings revealed that individuals residing in areas with higher population density exhibited a greater tendency to use bicycles and walking as modes of transportation. However, in areas with longer distances to metro stations, there was a decrease in the use of transit systems. Based on these results, the researchers concluded that attitudinal parameters held by individuals had a more significant impact on travel behaviour than the specific characteristics of land use.

Hendy et al. (1998) conducted a study focusing on walking and recreational trips in Austin. The researchers examined and developed models for walking trips, considering socioeconomic and environmental factors. Their findings indicated that shade, perception of safety, and the presence of other pedestrians on the road were significant factors influencing walking behaviour. In conclusion, the study emphasized the importance of these factors in promoting and facilitating walking as a mode of transportation and recreation in the Austin area.

Cervero (1996) conducted a study that involved modelling data from eleven urban areas. The research utilized American Housing Survey data to examine the relationship between land-use parameters and mode choice. The findings indicated that individuals living in high-density areas, households without cars, and those residing near their workplaces were more likely to use transit systems as their mode of transportation. This suggests that land-use characteristics such as density and proximity to jobs significantly influence mode choice, particularly favouring transit use in the identified scenarios.

Carne et al. (1998) examined a model using San Diego County travel diary data. The study investigated the impact of various explanatory variables such as income, prices, and the built environment. Specifically, the researchers focused on analysing the effects of density, street patterns, and distance from downtown on travel behaviour.

Boarnet et al. (1998) conducted a similar primary travel demand model to examine the impacts of the built environment on modal choice. They analysed both non-work travel decisions and the choice of residential neighbourhoods together. The study found that retail density and employment significantly influenced modal choice.

In Kockelman's thesis (1998), an analysis was conducted to explore the relationship between non-work travel and urban form features. Factors such as mixed land use, accessibility, density, travel time, and cost were considered. The research findings indicated that urban form characteristics did not directly influence the demand models. These studies provide evidence of the relationship between travel decisions and land-use characteristics. From the literature review, it can be concluded that individuals living in areas with high density are more likely to utilize walking and public transportation systems as modes of transportation.

Ewing et al. (2000) carried out a study to understand the relationship between urban sprawl and traffic-related fatalities. They gathered data from 448 districts across 101 cities in the United States and created a 'sprawl index' using principal components analysis. This index aimed to quantify the degree of urban sprawl in each location. The researchers then used regression analysis to explore potential correlations between this sprawl index and the rates of traffic accidents. Their findings were significant: with every 1% increase in the sprawl index, there was a corresponding increase of 1.49% in traffic fatalities and a much steeper increase of 3.56% in pedestrian fatalities. The conclusions drawn from this research highlight a strong connection between urban sprawl - characterized by extensive suburban development and dependence on motor vehicles - and an increased likelihood of fatal traffic accidents. These findings underscore the importance of urban planning strategies that limit sprawl and promote more compact, pedestrian-friendly cities.

Dieleman et al. (2002) explored the connections between individual attributes, socioeconomic characteristics, urban features, and travel mode selection in their research. They collected data from the Netherlands' National Travel Survey (OVG), including income, car ownership, household type, education, residential environments, trip purpose, and travel behaviour. The research used statistical models, including the multinomial logit model, to investigate the relationship between individual characteristics, socioeconomic factors, urban features, and mode choice for travel. The study investigated the relative significance of personal attributes and residential circumstances' features as determinants of transportation mode choice and travel distance. The findings showed that both personal characteristics and residential circumstances' features maintained a robust and significant relationship with travel behaviour in multivariate travel behaviour models. Thus, the study implies that understanding these individual and residential factors can provide valuable insights for shaping transportation policies and urban planning strategies.

Ewing et al. (2003) undertook a study to measure urban sprawl and evaluate its correlation with transportation outcomes. They used the newly formed Rutgers-Cornell urban sprawl indicators and overall sprawl ratio. The research operationalized urban sprawl by integrating multiple factors into several elements: density, land use mix, degree of centring, and street connectivity.This combination of factors was executed using principal component analysis. These elements were then correlated with variables such as car ownership, travel mode selection, travel time, per capita vehicle miles travelled, traffic delay, and per capita traffic accidents. This correlationwas established using multiple regression analysis. For most travel and transportation outcomes, it was found that areas with a high degree of urban sprawl fared worse than compactareas. The exception was congestion, measured in terms of per capita traffic delay, which did not favour compactness over sprawl. Sprawling areas distributed congestion more evenly. However, they also generated significantly more vehicle miles travelled (VMT), offsetting thebenefits of dispersal.

The study conducted by Schwanen in 2004 evaluated the outcomes of the Netherlands' national physical plan strategy on individual journey behaviour. The research examined four elements of this strategy: concentrated decentralization in the 1970s and 1980s, the compact-city strategy of the 1980s and 1990s, the A-B-C location strategy, and the spatial retailing strategy. The information utilized in the study was derived from the 1998 Netherlands National Travel Survey (NTS). In summary, the study found that the national spatial plan in the Netherlands had a positive impact on promoting biking and walking in urban areas, particularly for shopping trips. However, it was less effective in reducing travel times, as the construction of new districts and greenfield communities did not lead to noticeable improvements in this aspect.

Schwanen et al. (2005) pursued a study to explore how travel modal choice differs by residential neighbourhood and neighbourhood type disagreement. This study collected data from a San Francisco Bay Area household survey. The study's findings showed that the degree of neighbourhood type is significantly linked with the travel mode choice. Specifically, residents living in dissonant urban areas are more likely to commute using private cars than individuals residing in consonant urban areas. Hence, the physical form of the neighbourhood independently influences the choice of commute travel mode. The study also uncovered an interactive effect between neighbourhood-type dissonance and commuters' beliefs about car use, suggesting that these should be considered when analysing the intertwined choices of household location and travel mode.

Kasanko et al. (2006) conducted an in-depth study analysing the relationship between urban land use evolution and residential density in fifteen European urban areas. To do so, they used a variety of parameters, including the percentage of built-up area, annual growth rate of the built-up area, percentage of residential area, annual growth of the residential area, type of unbuilt land available, loss of natural and agricultural area, and density in both residential and built-up areas. The analysis showed a considerable expansion of built-up areas across all cities studied. The research also revealed that most surveyed areas were experiencing dispersed growth. As a result, the researchers categorized the cities into three groups: compact southern urban areas, northern and eastern urban areas with more relaxed structures, and areas with moderate densities primarily situated in the northern and eastern parts of Europe.

Burapatana et al. (2007) aimed to comprehend the influences of population density on travel behaviour. They relied on data from 1999 to 2005 by the Bangkok Metropolitan Administration (BMA). This investigation revolved around how land-use measures, specifically population density, impact the origination and destination of trips. The study's findings suggest that the population density in the central business district (CBD) is diminishing while increasing in suburban areas. This trend of suburbanization is leading to the transformation of natural spaces into residential areas, highways, and other infrastructures, subsequently resulting in a rise in air pollution due to a significant increase in the number of low-capacity vehicles. In response to these findings, authors propose transit-oriented planning and further investigation on vehicle kilometres travelled (VKT) in Bangkok. These measures would aid in mitigating the adverse environmental impacts of increasing suburbanization.

Aguiléra et al. (2009) examined the relationship between employment suburbanisation in Paris, the growth of reverse commuting (which refers to a round trip usually made from an urban area to a suburban one in the morning, returning in the evening) and changes in the weekday travel habits of central business district (CBD) workers over 20 years. They concluded that the transportation mode choice depended on the work location and, more specifically, the connection between residential and work areas. They observed that when public transportation was of high quality, it saw high adoption rates, even amongst wealthier inhabitants with access to personal vehicles. They suggested that enhancements to public transportation were necessary to reduce car usage. Gennaio et al. (2009) researched to evaluate the effects and efficiency of urban containment policies. These strategies, such as greenbelts and urban expansion boundaries, are widely usedas planning tools to control city sprawl. The research involved examining the extension of developed areas, shifts in the number of buildings, and the density of constructions inside and outside of residential areas in four municipalities in Switzerland, spanning from 1970 to 2000. The results showed that the imposition of urban expansion boundaries increased building density. Generally, an enhancement in building density was observed within the demarcated building zones.

Pan et al. (2009) conducted a study to comprehend the influence of urban spatial transformation on travel behaviour. Data was collected from 1709 individuals on various socioeconomic and travel characteristics, encompassing age, gender, income, family cycle count, car ownership, trip purpose, travel time, travel distance, and speed. In addition, they combined data regarding the urban area's attributes such as area size, distance to the closest city sub-centre, land usage, population density, block size, road density, number of bus stops and number of rail stations. Through the application of statistical models and a mode choice model, the study concluded that strategic land-use planning and thoughtful urban design can profoundly impact residents' travel behaviour and modal demand. These findings highlight the potential for shaping sustainable transportation in China's urban areas through informed urban planning and design strategies. Travisi et al. (2010) examined the relationship between urban sprawl and city transport systems. Utilizing a mobility impact index (IMPACT) created based on travel data from 739 Italian urbanareas, they studied the dynamics and factors influencing travel impacts. The study revealed thatover a decade (1981–1991), the effect of mobility in Italian cities had increased by up to 37%.This rise was primarily attributed to a shift in preference towards private low-capacity vehicles,specifically cars. As the usage of private vehicles increased, so did the environmental impacts and the associated costs of travel, consequently leading to a decrease in the quality of life. Theseadverse effects included air pollution, noise pollution, parking costs, and traffic accidents.

Interestingly, the study found that the commuters did not absorb these costs but instead affected wider communities. Despite the outlined negatives, the convenience and independence from public transportation offered by cars seemed to hold considerable value for many people. Additionally, the study suggested that as urban sprawl increases the separation between work and residential areas, the need for longer commutes increases, subsequently reducing the self-containment capacity of cities. Ambarwati et al. (2014) concentrated on analysing the evolution of Public Transport (PT) supply in conjunction with suburban development. The improvement of PT was strategized by planning Light Rail Transit (LRT) and BRT systems. The advancements in Mass Rapid Transit (MRT) systems were found to influence settlement development significantly. A balance between employment and community density was proposed as an alternative urban spatial policy. The study concluded that it is essential to integrate space-transport enhancement policiesto manage the growth of suburban settlements. This integration aims to reduce travel time by 10% and double the potential usage of PT modes, contributing to more efficient and sustainableurban development. Zhao et al. (2014) used a multiple regression analysis (MRA) to investigate the relationship between urban structure and travel patterns. The travel data was obtained from a household survey conducted in Beijing in 2006. Participants were asked to provide details such as averageone-way travel time, mode of transport for work trips, and socioeconomic attributes. Additionally, they were requested to share their preferences and opinions about residential location choices. The study's findings highlighted that urban structure characteristics significantly influence workers' use of cars and the travel duration for work trips. Urban sprawl,defined by lower density, poor jobs-housing balance, and limited access to public transport, was found to be detrimental in efforts to reduce private vehicle usage. As such, this research provides valuable insights into how changes in urban structure can influence transportation choices and patterns. Yao et al. (2014) explored the interconnection between people's choice of transport modes andtheir places of residence during the suburbanization process. This research used field survey data, statistical analyses, and Geographic Information System (GIS) techniques to facilitate their investigation. The results show a clear preference for public transport among the respondents. Walking or cycling was associated with the shortest travel distances, whereas buses and mass transit systems covered the most extended distances. Interestingly, using cars and taxis seemed to have a minimal correlation with travel distance. The study also highlighted the crucial role of public transportation, especially mass rapid transit systems, in influencing residential relocations in Beijing. This finding offers a compelling explanation for the urban sprawl observed during the city's suburbanization process. Engelfriet et al. (2017) explored the influence of various urban structure variables on travel behaviour. The study specifically looked into the impact of city size, urban area density, mixed land use, polycentricism, and spatial clustering, with travel behaviour measured in terms of timeand distance. The research used a methodology to calculate these urban variables and their subsequent impact on travel. The study found that city size and spatial clustering significantly influenced travel behaviour. Specifically, larger cities without defined clusters of businesses and other amenities led to longer average travel times and distances. Based on these findings, the researchers advocated for spatial planning measures that promote or strengthen high-densityclusters, as these could help reduce travel time and distance. They also cautioned against current trends of urban sprawl, stating that such development could have detrimental long-term effectson city accessibility in China. Furthermore, it could intensify existing economic challenges. Tian et al. (2017) conducted a study to measure the extent of urban sprawl in the context of local circumstances and available data. The researchers gathered various land use and demographic data, including cultivated areas, grasslands, forests, lakes, urban and rural residential areas, isolated construction land, unused land, and population numbers. The study then established a multidimensional index that integrated urban expansion, urban compactness,and urban form to quantify urban sprawl. The analysis revealed that urban sprawl was more pronounced in the 2000s than in the 1990s in Shanghai, with noticeable spatial variations across different parts of the city. Interestingly, the study discovered a strong correlation between planning and urban sprawl, suggesting that the sprawl in Shanghai was a type of "planned sprawl." The researchers suggested the need for future planning strategies to aim for more sustainable and compact urban development. Ye et al. (2016) developed a structural equation model to quantitatively examine the relative impacts of urban form, trip attitudes, and trip features on commute satisfaction. The data utilized in the research were collected from a mainly composed survey. The investigation considered the inhabitants of Xi'an aged over eighteen who are employed in Xi'an. Respondentsfor the questionnaire survey were selected from their companies, and the survey was administered at their companies' locations. The model outcomes indicated that travel features, including modal choice, congestion, and level of services of public transportation, all directly impact travel satisfaction. Moreover, travel attitudes can directly and indirectly influence travelsatisfaction, while urban forms can have indirect impacts by influencing travel features. Hu et al. (2018) utilized individual-level travel data from the Beijing Household Travel Survey(HTS) to investigate the influence of urban form on travel patterns in Beijing, China. Theyemployed multilevel regression models to separate this rich data set, using the availableresources to gain deeper insights into the relationship between urban development and travelbehaviours. The results illuminated the differences in travel distances and times across variousurban and suburban areas, showcasing how the evolving urban structure could impact travel patterns and potentially intensify transportation difficulties in expanding Chinese urban areas. Hu et al. (2019) evaluated empirical literature discussing the link between urban form and travelbehaviour in Chinese cities. Their study established that residential suburbanization in isolationleads to increased trips. Polycentric development exhibits mixed impacts on travel while job-housing balance leads to a decrease in trips. Additionally, the researchers compared the experimental findings regarding the relationship between urban form and travel in Chinese cities and those observed in different countries. This comparison highlighted unique elements within Chinese urban contexts. In conclusion, Hu et al.'s research identified specific contextualfactors that explain the unique relationships observed in Chinese cities. The study reinforces the need for considering regional or cultural contexts when exploring the interplay between urban form and travel behaviours.

## 2.5 Summary of Literature Review

Numerous studies have explored how Bus Rapid Transit (BRT) systems are planned and work in different cities around the world, like Bangkok and Bogotá. These research works show that careful planning, considering how people move about, and working with the community are vital for the success of BRT systems. Researchers have looked at various aspects, such as how these systems affect traffic, pollution, and even the local economy. various factors impact the introduction and operation of BRT systems, including but not limited Demographics influence the effectiveness and sustainability of BRT systems in different global contexts, Political support can dictate the efficacy of BRT systems operational and technical aspects like travel demand, travel time, and possible synchronization of BRT vehicles. BRT systems can influence areas like air quality and urban renewal while sometimes being impacted by declining user satisfaction. The past studies revealed that modal shift refers to the transition of transport users from one mode of transportation to another. In the context of introducing a BRT system, it pertains to theshift of commuters from their existing transport modes (like private vehicles, conventional buses, bicycles, or walking) to the new BRT system. nfluential factors affecting modal shift, especially towards a BRT system, may include: Travel time, if the BRT can offer reduced or competitive travel times compared to existing modes, users may shift towards it. Cost, the affordability or cost savings offered by the BRT compared to private vehicles or other public transport modes. Convenience, factors like ease of access, frequency of service, and comfort can entice users to switch to the BRT system. Safety, perception and reality of the safety of using the BRT system, compared to other available options. Environmental Concerns, a wareness and concern for environmental impacts (like emissions from private vehicles) could motivate users to prefer the relatively eco-friendly BRT. Socioeconomic Factors, Attributes such as income, age, and gender, which might influence a person's willingness or ability to change transportation modes. Infrastructure, Adequate and user-friendly infrastructure like dedicated lanes, easy boarding facilities, etc. Land use and its impact on transportation mode choice has been widely studied, emphasizing the interplay of various factors. Key elements include density, diversity, and design of urban environments, which collectively influence public and non-motorized transport usage. Proximity to transit points and accessibility of destinations are pivotal in encouraging public transit use, while demographic variables and policy frameworks also steer choices. Additionally, social, cultural, and environmental factors interweave with physical land-use attributes to shape transportation behaviors. Nonetheless, a comprehensive understanding of how these elements interplay in different urban and policy contexts, especially amidst evolving technologies, remains an area warranting further exploration. While some studies have analysed the factors that influence BRT corridor selection. However,there is a need for more empirical research that uses four-step-methods to identify the most appropriate corridors for BRT systems in urban areas with high travel demand. In prior research, the focus was primarily on analysing the shift from private cars and motorcycles to transit systems. However, the shift from rickshaws, share-taxis, and cars to BRT systems has been overlooked, despite factors like waiting time, station type, corridor type, air conditioning availability, station distance, travel time, and travel cost being influential. While previous studies have explored the connection between travel behaviour and mixed land use/density, there remains a research gap in understanding how density influences mode choice in various traffic zones. This gap includes examining residential density, employment density, student density, and road density as contributing factors.

### 1.6 Scop of the Study

Certainly, the connection between land-use and travel behaviours is shaped by a complex interplay of multiple factors. Recent findings underscore the substantial influence of urban form on urban transportation systems, an influence that evolves over time and consistently contributes to significant issues like congestion, pollution, and resource depletion. Consequently, it is advisable to thoroughly analyse the relationship between land-use and transportation systems before utilizing it as essential data for infrastructure planning and decision-making processes. This study explores the potential implementationof the BRT system, with a special focus on itscorridor selection and ridership patterns in the urban areas of Kabul and Jalalabad cities. Furthermore, it presents an effective methodology to examine the interrelationship between land-use and travel behaviours. This methodology takes into account not only the current conditions but also anticipates changes in urban form and travel behaviours over time, aiming to develop a transportation solution that is sustainable, efficient, and responsive to the evolvingneeds of the urban population.

# CHAPTER 3

# RESEARCH APPROACHE FOR THE INTRODUCTION OF BUS RAPID TRANSIT SYSTEM

## 3.1 General

In recent years, the BRT system or metro surface has gained popularity worldwide as a flexible construction and cost-effective alternative for low and medium travel demand, particularly in small and medium-sized cities (Cervero 1998; Cervero 2013). This system provides reliable, secure, and convenient passenger trips (Rambaud et al. 2008). A study in the US revealed that 33% of passengers served by the introduced BRT system were new public transport users, while most other passengers had switched from private vehicles (Peak et al. 2005). This chapter focuses on travel demand in 22 districts (213 traffic zones) in Kabul City to understand the possibilities of implementing a BRT system regarding corridor selection. While the BRT system is cost-effective, implementing a standard BRT system requires significant financial resources. Therefore, sufficient ridership is essential for successfully selecting a proposed BRTsystem. Classical Travel Demand Modelling (four-step) is used to determine trip generation/attraction, trip distribution, modal split, trip assignment, and their associated parameters. TDM begins by introducing the study area and dividing it into several traffic zones, considering the traffic network in the system. The dataset includes base year data, network data,zone information, and future planning data (Figure 3.1).

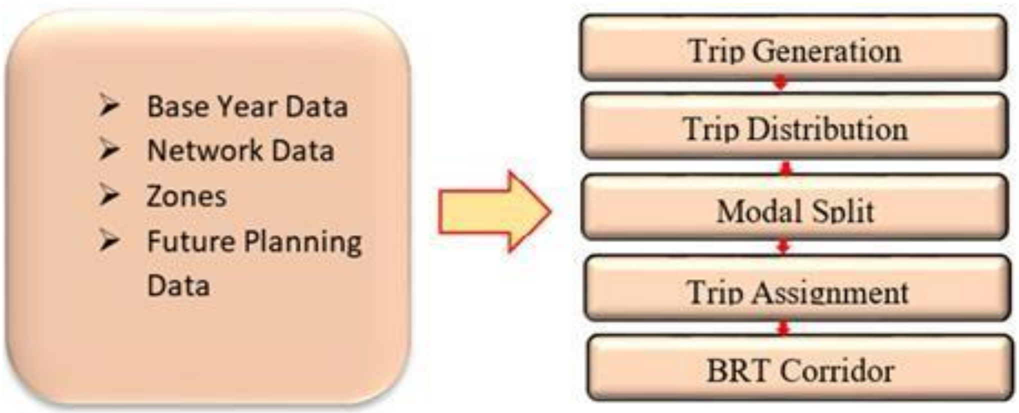



**Figure 3.1** Classic travel demand modelling

## 3.2 Kabul City

Kabul, the capital of Afghanistan, is known to have the world's fifth-fastest-growing urban population (Stanikzai et al., 2018 and Sadaat et al., 2018); situated in the northeastern part of the country, the city has experienced dramatic changes in land use and population over the last few decades. This is depicted in Figure 3.2. The region's current population stands at 5 million, spreads across a municipal area of 1,025 km2, and comprises 22 districts. Kabul Municipality is responsible for urban planning, construction, operation, and transportation system maintenance. The city began with a modest 400 hectares in District 1, also known as Share Kohna, in 1916. From 1992 to 1999, Kabul expanded considerably, growing to 68 $km^2$ and a built-up area of 25,000 hectares. Furthermore, the population increased at an average annual rate of around 4% during this period, and the city's Area expanded about 62 times. These variations in population and urbanization in Kabul city during these decades are outlined in Table 3.1, as per Kabul's Master Plan 2011.

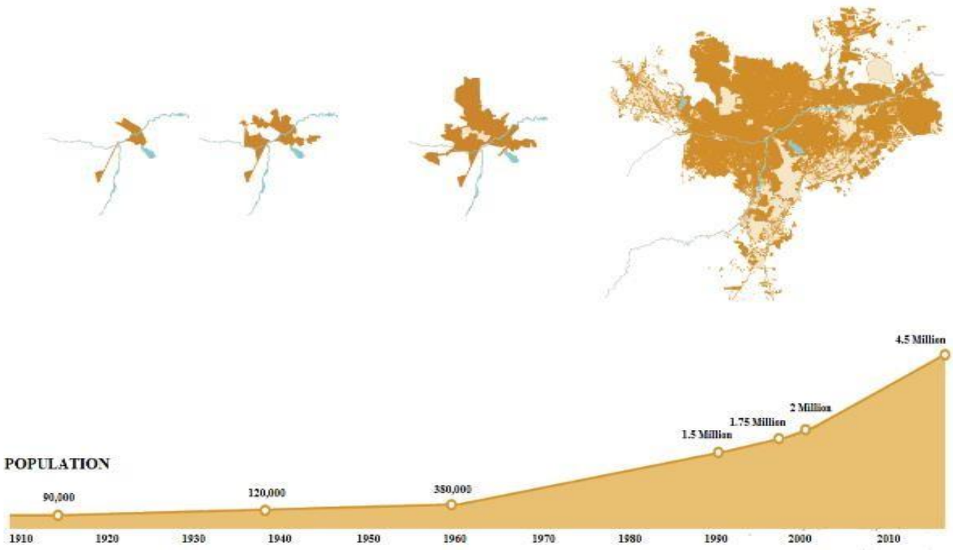



**Figure 3.2** Urban and pupation changes during the decades

Kabul's rapid urbanization has resulted from various factors, such as natural population growth, migration from rural areas due to insecurity, and the return of refugees from neighbouring countries. However, this rapid growth presents significant challenges, as it outpaces the development of the city's infrastructure, leading to primary service deficiencies for many residents, such as clean water, electricity, and waste management. Additionally, the transportation system in the city is under massive pressure, resulting in increased traffic congestion. The evidence shows trends in population growth and urban expansion in Kabul city. In collaboration with other related agencies, Kabul Municipality is trying to overcome these challenges and lay the groundwork for a sustainable future in Kabul. Efforts for improvement and expansion have been made, but the transportation infrastructure still requiressignificant development to meet the growing demands of the populace. Figure 3.3 indicates theKabul city map.

**Table 3.1:** Trends in population growth and urban expansion in Kabul City (KMP. 2011)

| Year | Population | Growth (%) | Area (ha) |
|---|---|---|---|
| 1700 | 10000 | - | - |
| 1878 | 50000 | - | 180 |
| 1916 | 65000 | - | 400 |
| 1925 | 90000 | 3.7 | 450 |
| 1940 | 120000 | 1.9 | 500 |
| 1962 | 380000 | 5.4 | 6840 |
| 1992 | 1500000 | 4.7 | 16830 |
| 1999 | 1780000 | 2.3 | 25000 |
| 2005 | 2721000 | 4 | 1022700 |

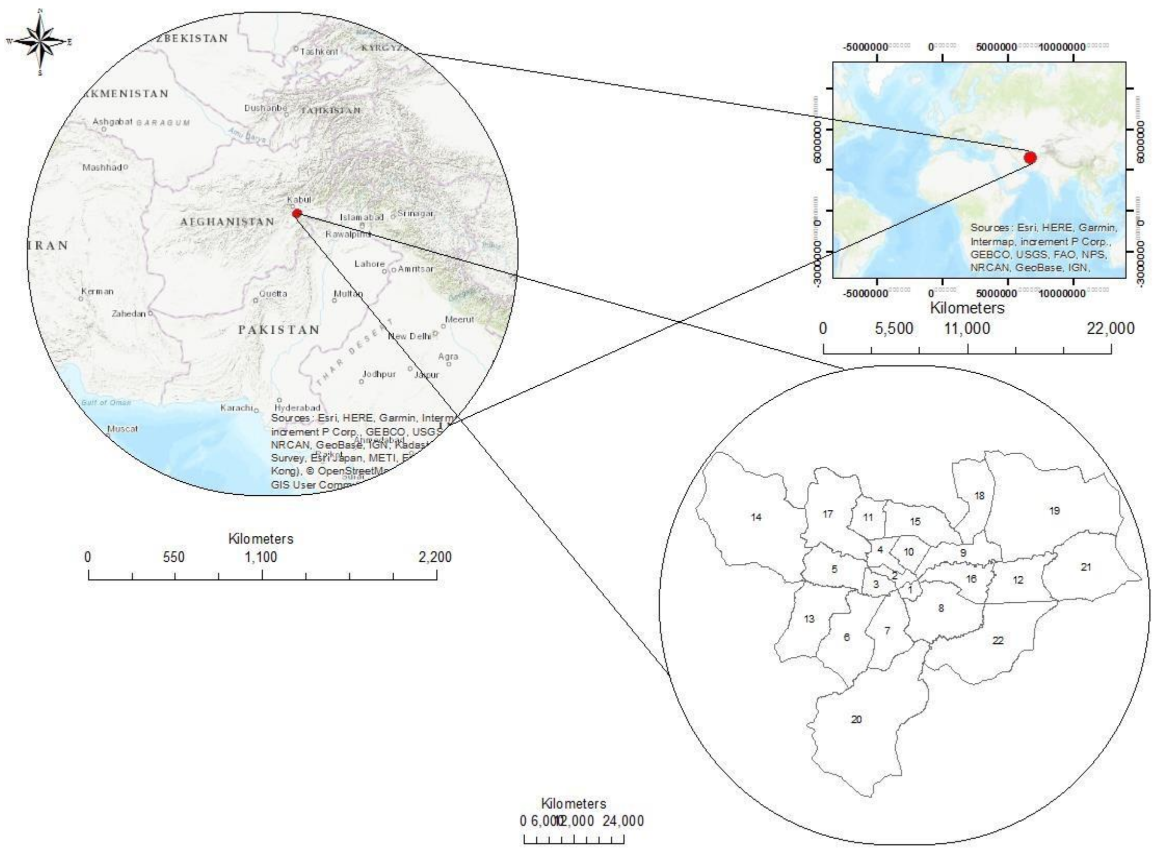



**Figure 3.3** Districts of Kabul City on GIS platform (22 Districts)

In 2005, the population of Kabul stood at 2,268,300. By 2008, this number had grown significantly, reaching 4.22 million. In January 2005, an agreement between the Ministry of Interior, the Kabul Province, and the Kabul Municipality expanded the jurisdiction of the Kabul Municipality. Consequently, the population of the newly incorporated areas surged, raising the total population to 2,721,000 people spread across 22 districts. Figures 3.4 and 3.5 illustrate the built-up Area and population distribution within Kabul city, respectively. This rapid growth is reflective of the broader urbanization trends within Afghanistan and has resulted in unique challenges for the city. The acceleration in the city's population has put a strain on existing infrastructure and services, necessitating innovative solutions and careful urban planning to accommodate the increasing demand. Despite these challenges, the city's growth also presents opportunities for economic development and increased social mobility for its residents.

This information highlights the challenge that city planners face in Kabul. With the majority of the population living in unplanned areas, there is a pressing need for comprehensive urban and transportation planning strategies to improve living conditions and infrastructure in these zones. This could potentially involve housing projects, road construction, utility provision, and more. Additionally, the development of social services and economic opportunities in these unplanned areas is crucial to support sustainable urban growth. As projected in Table 3.2, the population of Kabul in 2008 was estimated to be 4.2 million. Interestingly, the residents of the unplanned zones constituted 73 percent of this total population. Figure 3.4 illustrates the rapid urbanization growth trend in Kabul city spanning from 1940 to 1999, showcasing a substantial increase in its urban population and infrastructure development. This growth in urbanization brought along shifts in social, economic, and environmental dynamics, posing new challenges and opportunities for the city's management and inhabitants.

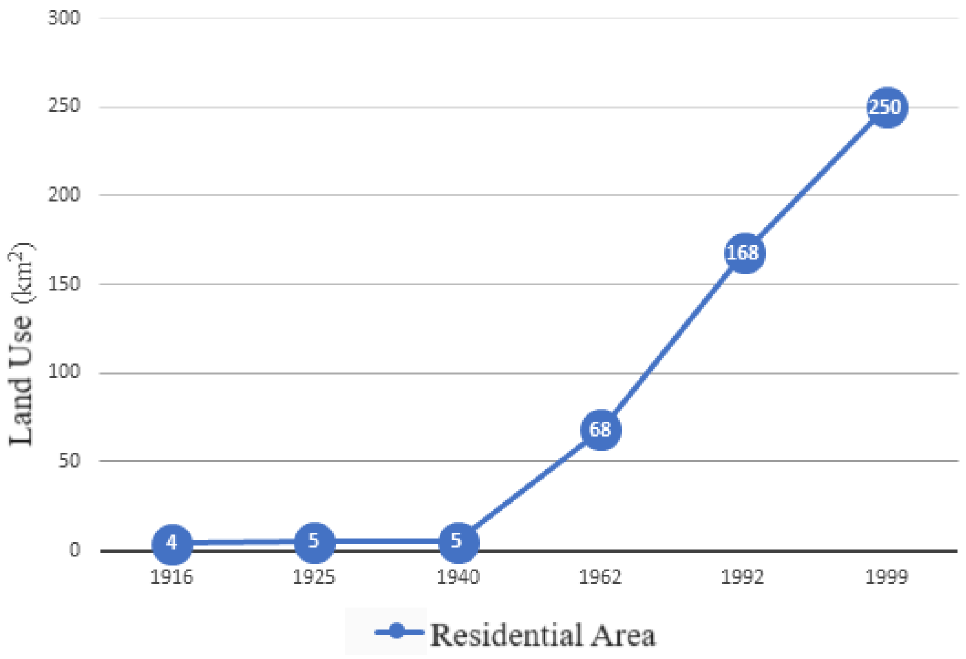



**Figure 3.4** Expansion of built-up Area in Kabul (Kabul Municipality 2011)

.As projected in Table 3.2, the population of Kabul in 2008 was estimated to be 4.2 million. Interestingly, the residents of the unplanned area constituted 73 percent of this total population.

Table 3.2 Population distribution and density in Kabul city (Kabul Municipality 2011)

| A No | B (ha) | C | D (p/ha) | E (p/ha) | F |
|---|---|---|---|---|---|
| 1 | 483 | 124 | 35,402 | 73 | 286 |
| 2 | 684 | 257 | 83,295 | 122 | 324 |
| 3 | 911 | 414 | 139,742 | 153 | 338 |
| 4 | 1,172 | 598 | 204,049 | 174 | 341 |
| 5 | 2,845 | 894 | 283,489 | 100 | 317 |
| 6 | 4,918 | 957 | 285,255 | 58 | 298 |
| 7 | 3,334 | 1,478 | 416,675 | 125 | 282 |
| 8 | 4,825 | 1,124 | 331,554 | 69 | 295 |
| 9 | 2,433 | 616 | 188,569 | 77 | 306 |
| 10 | 1,303 | 885 | 270,157 | 207 | 305 |
| 11 | 1,742 | 829 | 287,853 | 165 | 347 |
| 12 | 3,490 | 1,221 | 298,847 | 86 | 245 |
| 13 | 4,719 | 1,660 | 467,440 | 99 | 282 |
| 14 | 11,902 | 524 | 147,910 | 12 | 282 |
| 15 | 3,253 | 626 | 200,465 | 62 | 320 |
| 16 | 2,507 | 713 | 206,701 | 82 | 290 |
| 17 | 5,602 | 780 | 248,926 | 44 | 319 |
| 18 | 3,388 | 121 | 33,958 | 10 | 280 |
| 19 | 14,143 | 11 | 3,906 | 0 | 356 |
| 20 | 14,294 | 152 | 31,836 | 2 | 210 |
| 21 | 6,395 | 22 | 6,040 | 1 | 279 |
| 22 | 7,925 | 258 | 48,187 | 6 | 187 |
| Total | 102,270 | 14,264 | 4,220,256 | 41 | 296 |

"A" denotes Zone Area, "B" represents Residential Area, "C" indicates Population, "E" signifies District Density, "F" refers to another Residential Area, and "G" designates a different Zone Area.

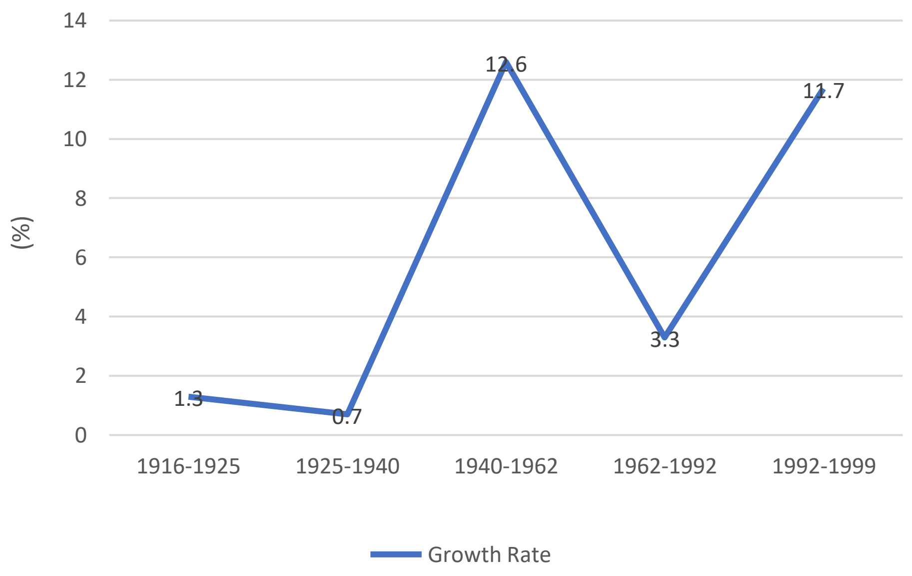



**Figure 3.5** Trends in annual population growth rate in Kabul City (KMP. 2011)

### 3.2.1 Urban Transportation Agencies in Kabul

Since 2002, investment in Afghanistan's road system has been initiated through government funding, international assistance, and private capital. The national Kabul ring road was among the first to be rehabilitated. This critical infrastructure allows Afghanistan to establish stronger connections with its neighbouring countries. Control over the transportation sector is not held by a single agency. Instead, three entities share responsibilities. The Kabul Municipality handles the organization, preparation, and maintenance of urban transportation infrastructure within its jurisdiction, including avenues and airports. The Ministry of Public Works (MPW) is in charge of the development, implementation, and maintenance of transport facilities like streets and railroads, with most of its programs being funded by international governments.

The Ministry of Transport and Civil Aviation (MOTCA) is tasked with making transportation policies and managing public transportation involving vans, planes, and other vehicles. Millie Bus Enterprises (MBE), a government-regulated company that owns and operates a bus fleet in Kabul and its surrounding areas, receives subsidies from the government. Having provided public transportation services in Kabul city for the past 40 years, Millie Buses is a mainstay of the city's transport system. Finally, the Ministry of the Interior handles issues related to commercial and additional information, it's worth mentioning that despite these advances, transportation in Kabul and across Afghanistan continues to face challenges. These include infrastructural deficiencies, security issues, and the need for further modernization.Overcoming these hurdles will be essential for improving accessibility and connectivity withinKabul and throughout the country, facilitating economic growth and social development in theprocess.

### 3.2.2 Urban Road Network in Kabul

Well-planned and effectively implemented road connectivity is vital for any urban area. It forms the backbone of a city's transportation infrastructure, allowing efficient movement of people, goods, and services. This fosters economic growth and social development by facilitating access to employment opportunities, educational institutions, healthcare facilities, and other essential services. In areas with strong road connectivity, public transport can operate more effectively, reducing reliance on private vehicles and consequently alleviating traffic congestion and air pollution. This also supports the city's sustainability efforts by encouraging environmentally friendly modes of transport like cycling and walking. On the other hand, regions with poor road connectivity can face numerous challenges. good road connectivity is not just about transportation it plays a crucial role in shaping a city's social fabric and economic potential, contributing to the overall quality of life for its residents. Kabul's road network extends in a radial pattern from the city centre towards the north, northwest, west, southwest, south, and east. The entire network spans a total length of 330.7 km and is divided into two categories: arterial and main arterial roads. Surveys indicate that three regional four-lane highways and one national two-lane highway pass through the Central Business District (CBD). Arterial roads, made of asphalt and comprising no fewer than two lanes, serve to connect various districts with the city centre. In turn, these arterial roads are linked to local communities through secondary roads. Table 3.3 provides a summary of the road lengths and densities for each district under the jurisdiction of Kabul Municipality, segregated by road type. The average road density varies significantly among the districts. For instance, Districts 17 and 22, located in the suburbs, have the lowest density, at less than 5.0 km/km$^2$. Conversely, Districts 3, 4, 5, 10, 11, and 15, which are dominated by medium-rise apartments, boast an extremely high road density. Except for District 18, an older semi-urban area, the outer districts generally have poor road density.

Table 3.3 described as follow:

A: Main Arterial Road (km) , B: Arterial Road (km), C: Secondary Road (km) D: Community Road (km), E: Other Road Types (km), F: Total Road Length (km), G: Density (km/km$^2$

Table 3.3 Distribution of road and density in Kabul (Sector 9 Report 2009)

| Dis | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | 0.3 | 3.2 | 3.3 | 2.0 | 67.6 | 76.3 | 16.2 |
| 2 | 6.9 | 1.8 | 3.6 | 17.4 | 55.1 | 84.8 | 12.5 |
| 3 | 5.6 | 1.1 | 9.2 | 39.9 | 61.9 | 117.7 | 12.1 |
| 4 | 6.9 | 12.3 | 7.0 | 52.3 | 125.1 | 203.6 | 17.6 |
| 5 | 18.3 | 0.7 | 1.2 | 97.1 | 231.5 | 348.8 | 12.0 |
| 6 | 0 | 19.6 | 10.1 | 49.5 | 322.6 | 401.8 | 8.2 |
| 7 | 0 | 15.7 | 5.7 | 27.4 | 343.8 | 392.6 | 12.1 |
| 8 | 7.5 | 11.6 | 10.4 | 59.8 | 400.4 | 489.7 | 10.1 |
| 9 | 10.1 | 7.2 | 3.4 | 23.2 | 195.7 | 239.6 | 9.8 |
| 10 | 0 | 14.7 | 7.3 | 78.6 | 121.2 | 221.8 | 17.1 |
| 11 | 1.4 | 10 | 2.6 | 57.9 | 226.2 | 298.1 | 17.1 |
| 12 | 0.0 | 19.3 | 4.8 | 36.2 | 285.1 | 345.4 | 9.9 |
| 13 | 0.0 | 7.5 | 19.4 | 58.2 | 442.7 | 527.8 | 11.3 |
| 14 | 3 | 24.5 | 3.0 | 55.0 | 239.8 | 325.3 | 2.6 |
| 15 | 0 | 25.5 | 5.3 | 128.3 | 89.8 | 248.9 | 7.8 |
| 16 | 0.4 | 13.4 | 4.2 | 9.8 | 228.1 | 255.9 | 10.2 |
| 17 | 9.6 | 0.0 | 8.1 | 12.2 | 245.8 | 275.6 | 4.9 |
| 18 | 0 | 14.1 | 18.0 | 54.0 | 38.8 | 124.9 | 3.7 |
| 19 | 15.5 | 0.0 | 24.1 | 36.2 | 220.1 | 295.8 | 2.1 |
| 20 | 17.8 | 0.0 | 7.9 | 81.9 | 148.8 | 256.4 | 1.8 |
| 21 | 10.9 | 0.0 | 7.0 | 35.8 | 3.4 | 57.1 | 0.9 |
| 22 | 0 | 8.8 | 17.6 | 52.8 | 189.4 | 268.6 | 3.4 |
| Total | 114.1 | 211.0 | 183.2 | 1,065.4 | 4,282.8 | 5,856.5 | 5.7 |

Main arterial and arterial roads serve as critical transport roads in the city of Kabul, facilitating the flow of traffic through the Central Business District (CBD). These roads, which link various neighbourhoods and districts of the city, play a substantial role in sustaining Kabul's socio-economic activities. However, numerous challenges affect the condition of these roads. Their age is a significant factor: many roads were laid years ago and have suffered substantial wear and scratch since then. This damage is compounded by insufficient drainage systems, which can lead to water accumulation and further damage the road surface. This is especially problematic during the rainy season, when standing water can accelerate erosion and the formation of potholes. The heavy vehicle volume on these arterial roads is another contributing factor to their deterioration. High traffic loads exert significant stress on the road surfaces, especially where larger vehicles such as buses and trucks are concerned. The constant pressure leads to the faster degradation of the asphalt concrete, causing potholes, rutting, and other forms of surface damage.

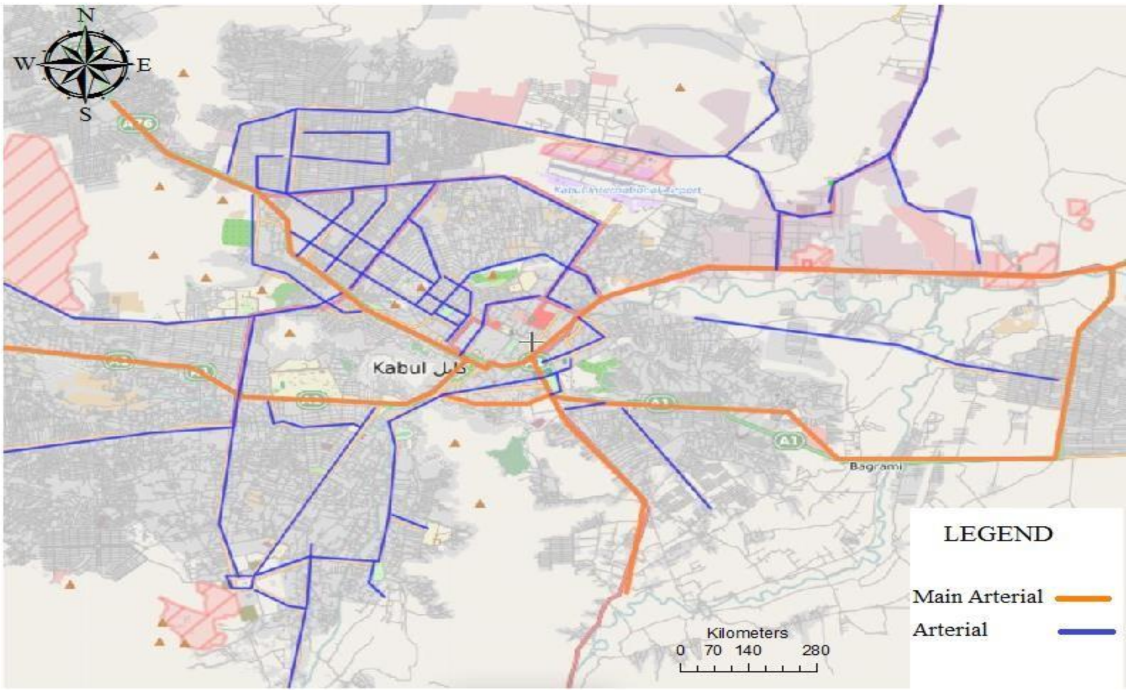



**Figure 3.6** Main arterial and arterial road network in Kabul city (GIS)

Figure 3.6 provides a visual representation of Kabul's road network, highlighting the extent of arterial and main arterial roads. In complement to this, Table 3.4 provides an overview of the current condition of these roads. Different modes of transportation are recognized as public transport in Kabul city. These include standard buses, minibuses, minivans, and shared taxis, all providing vital links across the urban landscape and beyond. These varied transportation options offer flexibility for commuters, catering to different travel needs and preferences.

**Table 3.4** Assessment of road condition in Kabul city (Kabul Municipality 2009)

| Road Type | Good | Fair | Poor | Very poor | Total (km) |
|---|---|---|---|---|---|
| Main arterial | 96.7 | 6.5 | 5.6 | 5.3 | 114.1 |
| Arterial | 29.5 | 23.7 | 109.3 | 38.5 | 211.0 |
| Secondary | - | 16.8 | 11.5 | 154.9 | 183.2 |

The Millie Bus Company (MBC) is an integral part of this public transportation network. Funded by the government, this entity is tasked with providing affordable transportation solutions, particularly catering to low-income individuals. This critical service not only facilitates daily commuting but also helps in alleviating economic barriers by improving access to job opportunities and essential services across the city. The city bus system is extensive, covering 54 routes with ten strategically positioned terminals throughout the city. This network spans a total distance of 473 kilometres, with an average service length of 8.8 kilometres per line. The broad coverage of this network ensures that most areas of the city are within a reasonable distance of a bus route, enhancing the accessibility of public transport for Kabul's residents. MBC operates 601 buses within Kabul, but due to various issues, only 358 of them are currently operational. This shortfall represents a challenge to the efficiency and capacity of the public transportation system, and resolving these issues should be a priority to improve service levels. In addition to MBC's fleet, there are 44,924 privately-owned buses registered in Kabul city, out of a total of 48,513 countrywide. These private operators provide additional transport capacity. However, they operate without strict regulation, which can lead to problems such as traffic congestion, variable service quality, and safety concerns. The integration and regulation of these private operators into the broader public transport framework could help address these issues, enhancing the overall effectiveness and sustainability of Kabul's public transport system.

As previously stated, this study is primarily guided by three objectives. These objectives provide the framework for the research approach, which is visually represented in Figure 3.7. This flow chart outlines the methodological steps and followed to conduct the study. The methodological flow chart offers a visual breakdown of this process. Starting from the initial stages of research design and data collection, through to data analysis and interpretation of results, each step is associated with the key objectives. This comprehensive and systematic approach allows for a strong exploration of the research questions, ultimately generating valuable insights into the subject matter. The methodology of this chapter is divided into several steps to estimate Urban Travel Demand (UTD) and develop the Urban Travel Demand Modelling (UTDM) for Kabul city. The following is a breakdown of the methodology:

- Trip Generation/Attraction Model:

Linear Regression Model (LRM) is used to develop the first model. The purpose is to identify influential parameters and forecast travel patterns in each traffic zone. This model helps understand the factors that contribute to the number of trips generated or attracted in different areas.

- Trip Distribution Model:

The second model is developed using the Gravity Model (GM). The GM helps determine how trips are distributed among the traffic zones. Trip distance is considered as an independent variable in this model.

- Modal Choice Model:

The third model focuses on understanding how transport users select their mode of travel based on travel time. The Logit Curve Function (LCF) is used to develop the modal choice model. This model provides insights into the preferences and decision-making process of travellers when choosing between different transportation modes.

- Trip Assignment:

The fourth and final step is the development of a travel assignment model. This model assesses the road network performance based on various operational modes in Kabul city. It helps understand how different transportation options impact the traffic flow and efficiency of the road network. After implementing the four-step models, the results of UTDM are used to support the introduction of a BRT system in Kabul city.

The high travel demand identified in specific networks within the city provides a basis for the implementation of the BRT system. Furthermore, the integrated results of the modal choice model and land-use metrics from Chapter 4 provide insights into how users' mode choices are influenced by the level of urban compactness in each traffic zone. The methodology for this study is illustrated in Figure 3.8, which provides a visual representation of the different steps and their interconnections.

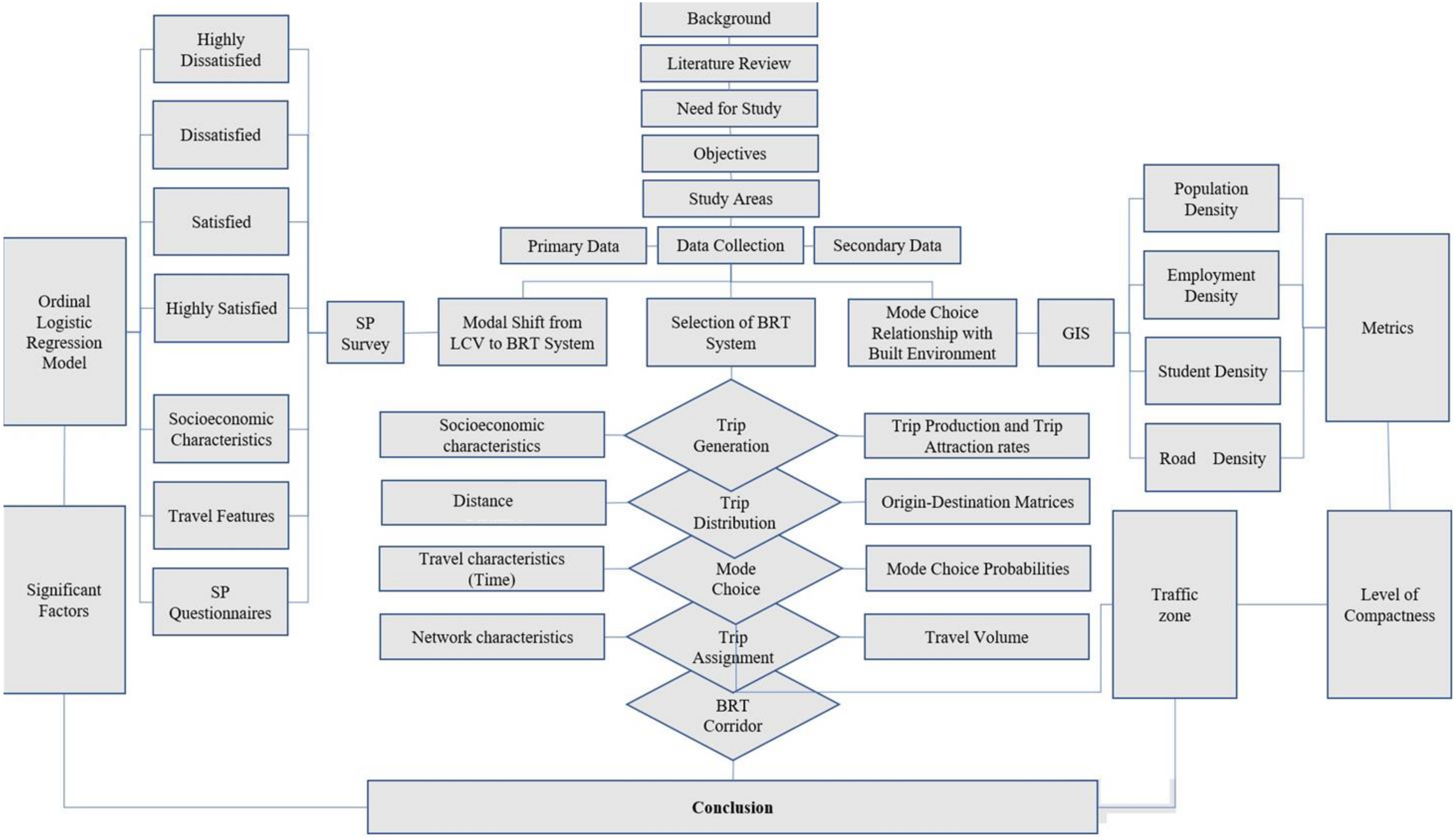



**Figure 3.7** Methodological flowchart for all objectives

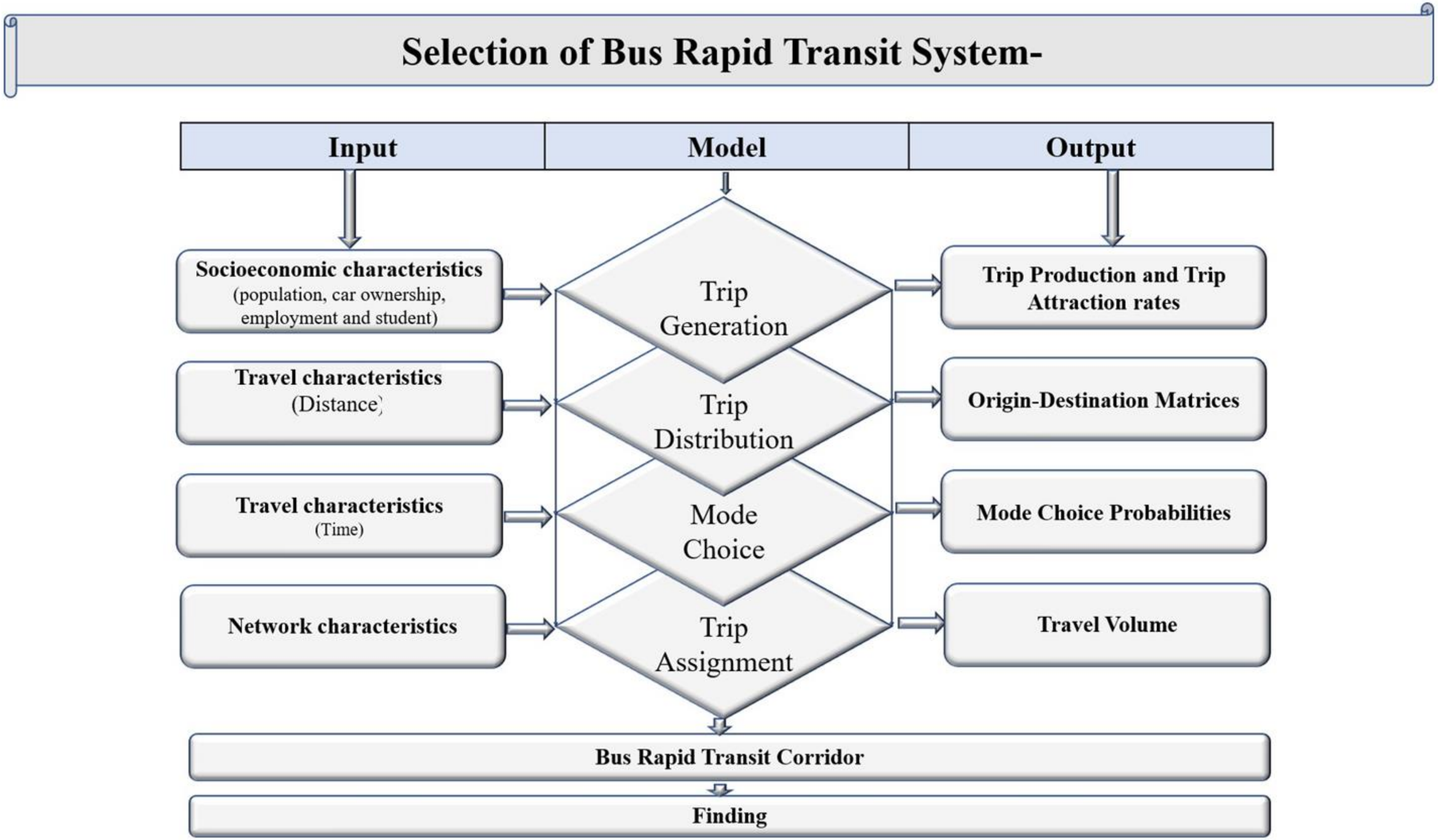



**Figure 3.8** Methodological flowchart for first objective

### 3.3.1 Data Collection for the Purpose of Travel Demand Modelling

This section discusses the data collection process. The data for this study were gathered form Final Report 8 Transportation (2009), which covers characteristics of households and their travel habits. Information such as the number of family members, district number, family size, car ownership, gender, age, and details related to travel (number of trips, origin and destination districts, addresses of each trip's origin and destination, mode of transportation, and trip purpose) were all recorded. This data also extends to the current population, employment, and traffic surveys, which include aspects of the road network, vehicle capacity, and traffic volume.

In 2009, a survey was conducted in Kabul. Surveyors visited random houses and recorded the regular trips of family members over the age of five. The city was thought to be divided into about 500,000 families, but this study only focused on a sample of 5,000 of them, or 1% of the total. The survey was carried out in each of the city's 22 districts (213 traffic zones). Ultimately, 4,153 households responded successfully, representing a total of 30,969 family members. The average family size was found to be 7.5 members, with a travel ratio of 39% and an average of 2.1 trips made per day.

Interestingly, the ratio of car ownership among the sample collected was high at 34%. This suggests that many of the households visited were middle class or above. In Table 3.5, can find a detailed breakdown of all the key metrics that have been gathered and analysed, including family size, district numbers, number of trips per day, and car ownership ratio, among others. This table presents a clear and organized collection of data points that make it easier to understand the distribution of these variables across the sampled population in Kabul. Figure 3.9 offers the way to view the data. The data for each traffic zone was collected in varying amounts.

As a result, each zone has its own expansion factor or rate, which is used to extrapolate or estimate the total information for that particular traffic district. This method ensures that the data accurately reflects the unique conditions and characteristics of each individual zone. The data collection process also included gathering information on travel times for each currently used motorized mode from one zone to another. This was integral to the survey, specifically for the model usage aspect. The survey was conducted across 28 locations in Kabul's 22 districts, with 22 samples taken at each location. The data collected encompassed all existing modes of transportation in the city, including buses, minibuses, microbuses, share-taxis, and private cars.

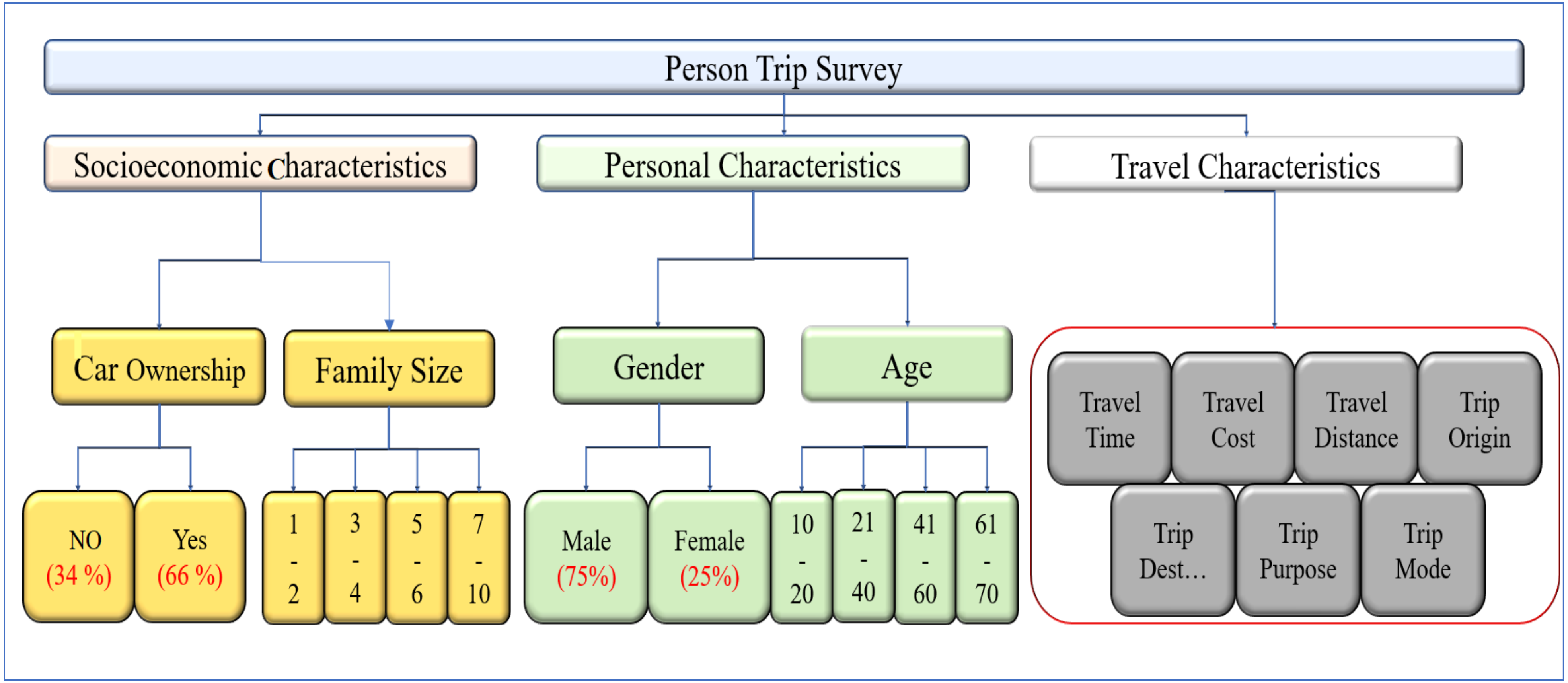



**Figure 3.9** Collected data through Final Report 8 Transportation (2009) and survey

To determine the spot speeds of vehicles. One of the manual methods employed for this purpose was the use of an enoscope. A base length of approximately 90 meters was marked on the road at the survey location. The enoscope was positioned at one end of this base length, with the observer located at the other end.

**Table 3.5** Summary of collected data (Final Report 8 Transportation, 2009)

| Surveyed households | 5,000 |
|---|---|
| Responded households | 4,865 |
| Effectively responded households | 4,153 |
| Number of households owning cars | 1,638 |
| Ratio of car ownership | 39.4% |
| Total number of family members | 30,969 |
| Average number of family members | 7.5 |
| Total number of persons going out | 12,179 |
| Ratio of going-out | 39.3% |
| Total number of trips | 25,643 |
| Unit rate of trips (net) | 2.1 trips/person |

The statistics in Table 3.6 provides an overview of each category, including, mean, standard deviation, min, median and max values

**Table 3.6:** statistics of the dependent and independent variables

| Category | Mean | Median | Max | Min | Std |
|---|---|---|---|---|---|
| Trip Generation | 121 | 83 | 582 | 5 | 101 |
| Trip Attraction | 121 | 110 | 312 | 32 | 54 |
| Car Ownership | 52 | 43 | 241 | 1 | 43 |
| Student | 44 | 40 | 166 | 1 | 28 |
| Employee | 54 | 45 | 193 | 1 | 38 |
| Population | 197 | 155 | 677 | 22 | 136 |
| Pop Density | 2 | 1 | 20 | 0 | 3 |

This setup allowed for the identification of the spot speed for each individual vehicle using the enoscope. After the speed was determined for each vehicle, other factors such as the number of stops, average delay time at each stop, and the distance between traffic zones were taken into consideration. With these factors accounted for, the travel time for each mode of transportation was measured, as detailed in Equation 3.1.

$$\mathrm{T} = \frac{D}{V} + Number\ of\ stops\ x\ delay\ time\ at\ stop \quad (3.1)$$

The survey results and secondary data were compiled into an Excel sheet for analysis. As mentioned earlier in this chapter, the Urban Transport Demand Model (UTDM) was applied to the collected data.

Based on the results from this model, the corridor for the  BRT system was selected.

### 3.3.2 Zoning of The Kabul City

Kabul city is divided into 22 districts, also known as "nahias," each with its specific administration and governance structures. The districts are numbered and sometimes also have names associated with them, for example, District 1 is sometimes referred to as "Deh Afghanan." Each district varies in terms of population, development, and infrastructural facilities. As mentioned The city of Kabul spans 22 districts, covering a total area of 1025 square kilometres.

Data was collected from each of these districts, which are densely populated, with many housings more than 50,000 residents. This high population density may negatively impact the accuracy of results.

Many studies suggest the development of models for each traffic zone, which typicallycomprise smaller populations, to generate more precise results. In light of these recommendations, this study has divided the area of Kabul into 213 distinct traffic zones.

This division was based on the origin and destination addresses of each traveller; a process executed using Geographical Information System (GIS) software. A representative point, or centroid, was established in each of these traffic zones to facilitate data analysis (Figure 3.1).

These subdivisions will allow us to conduct a more detailed and examination of traffic patterns and behaviours. Moreover, it also helps to minimize the potential skewing effects of high population density on the research findings. By focusing on these smaller zones, we can ensure a more accurate representation of the local traffic conditions and thus provide a more solid foundation for any proposed traffic management solutions.

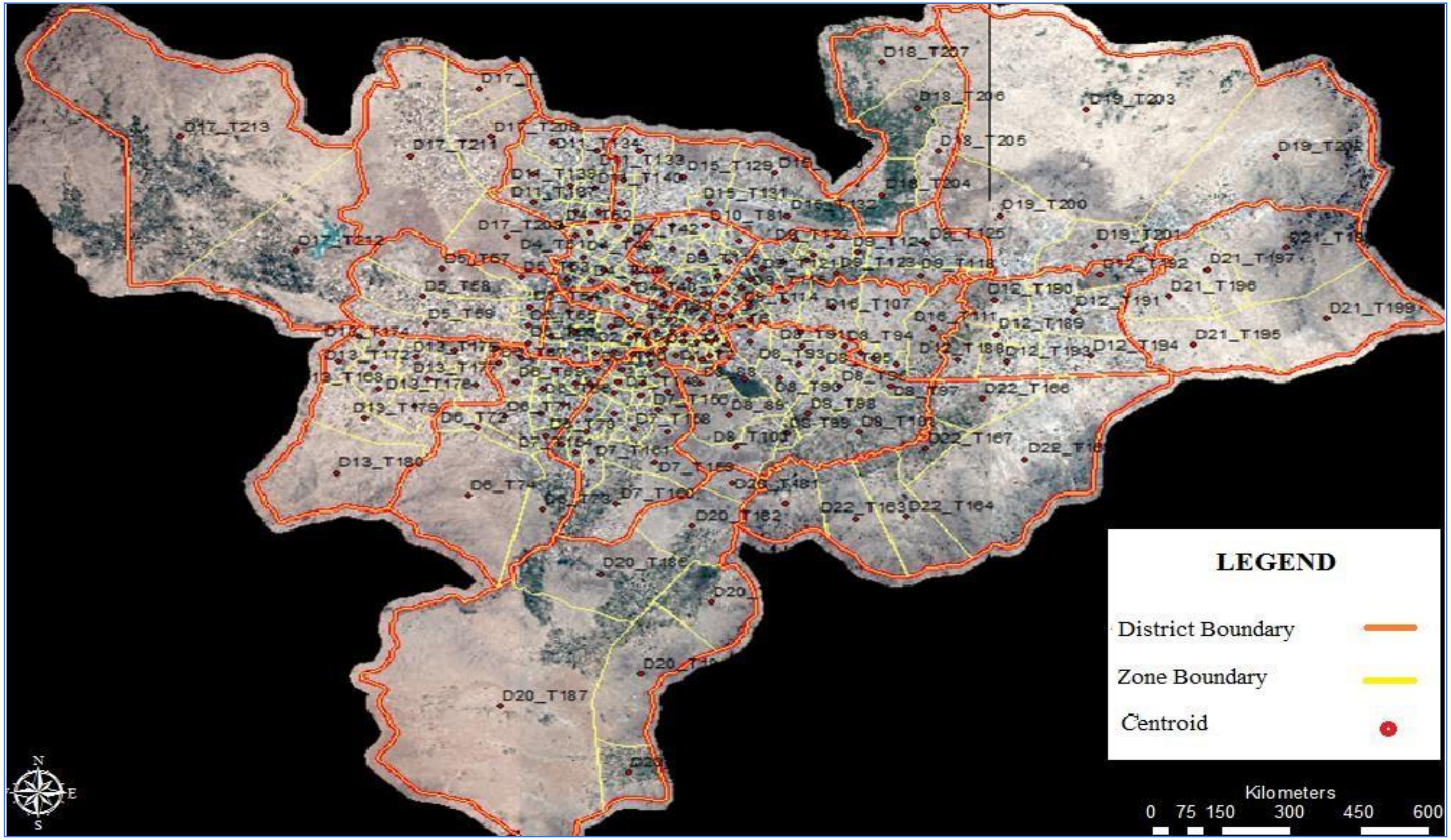



**Figure 3.10** Centroids in 213 traffic zones in Kabul city

### 3.3.3 Trip Purpose and Trip Mode in Kabul City

Figure 3.11 is a pie chart that illustrates the distribution of trip purposes based on collected data. It reveals that 19% of individuals travel for work, which could involve commuting or work-related tasks; 22% for school, including students and educational staff commuting; 4% for business, encompassing entrepreneurs and others who travel for business operations; 3% for shopping, covering all forms of retail activity. The largest segment is home at 30%, signifying all trips made by individuals returning home after their activities. Lastly, 3% is attributed to other reasons not specifically categorized, such as social visits or recreational activities. This visual representation allows for an immediate comparison of the relative frequencies of each travel purpose

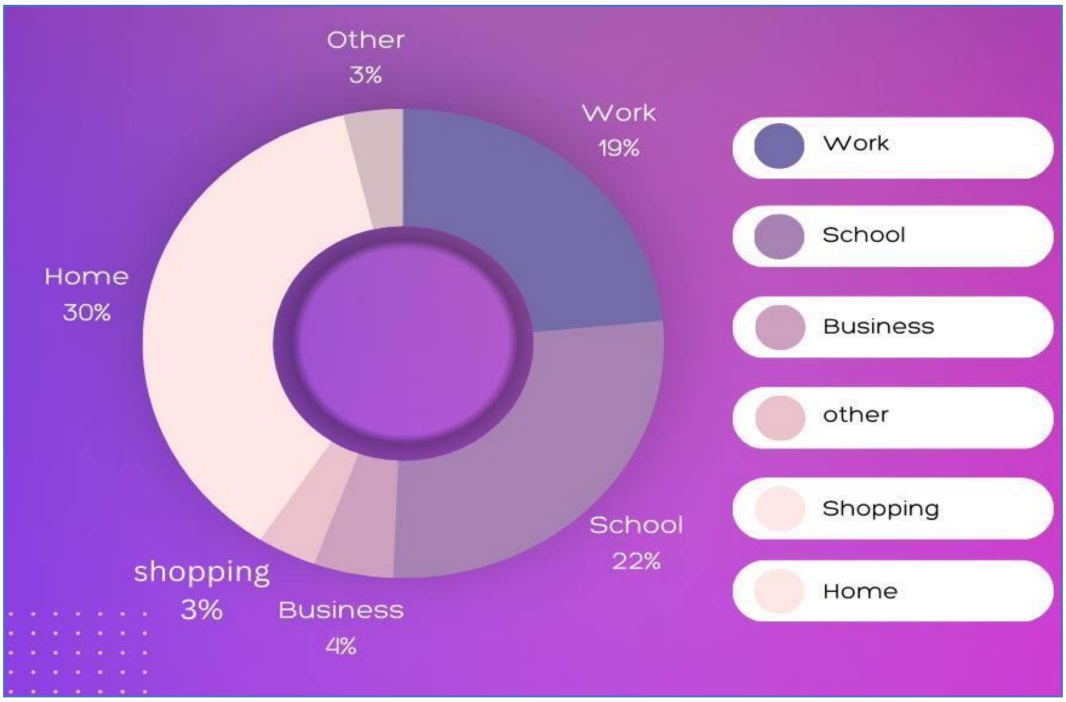



**Figure 3.11** Trip purpose in Kabul city

Figure 3.12 displays the distribution of transportation modes used by individuals based on collected data. It shows that 25% of people primarily use a car, demonstrating its significance as a personal mode of transport. Large buses are used by 12% of the population, illustrating their role in public transportation. Mini and micro-buses are used by 6% and 15% of individuals, respectively, indicating their role in bridging the gap between personal and public transport. The largest segment, however, is walking, which accounts for 42% of the chosen modes of transport, emphasizing its prevalence as a sustainable and health-conscious choice. This chart visually summarizes the relative popularity of each mode of transport.

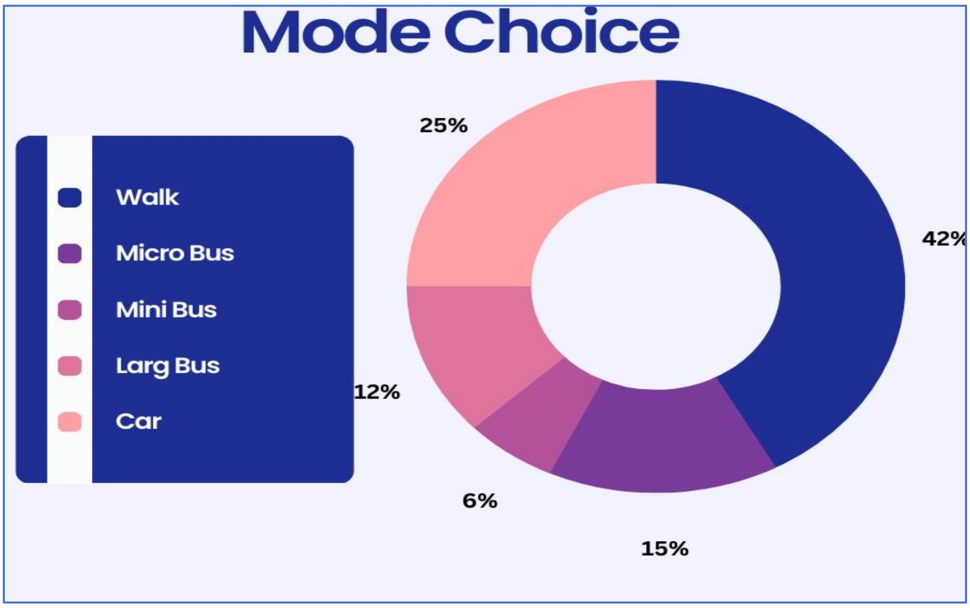



**Figure 3.12** Trip Mode in Kabul city

### 3.4 Analysing of Trip Generation Model

The trip generation stage of the classical transport model aims to predict the total number of trips produced by the Origin zone (Oi) and attracted to the Destination zone (Dj) in the study area. In other words, trip generation is the process by which measures of city activities are translated into numbers of trip generation and attraction among traffic zones in a specific study area. Moreover, the goal of the trip production and attraction step is to interpret the rationale behind travellers behaviour and generate a mathematical association that synthesizes the trip-making pattern based on observed trips, land use, and household characteristics. This can be accomplished in a variety of ways, beginning with the trips of individuals or households that live in each zone, or directly with any of the zone's characteristics, such as population, employment, number of vehicles, and etc.

There are many factors that affect trip generation, including income, car ownership, family size, household structure, land value, residential density, land use, school capacity, hospital capacity, and accessibility. In this study, car ownership and population and employment are considered as influential factors or independent variables for trip production, and population, employment and density for trip attraction using Multiple Linear Regression model.

#### 3.4.1 Multiple Linear Regression Model

Multiple linear regression is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. The goal of multiple linear regression is to model the linear relationship between the explanatory (independent) variables and response (dependent) variable.

In general, a multiple linear regression model provides insight into the relationship between the dependent variable and independent variables. For example, multiple linear regression can indicate how much trips may vary for every one-point increase in the population, keeping all other variables unchanged. The mathematical representation of the multiple linear regression model is given by:

$$Y=\beta 0+\beta 1X1+\beta 2X2+\ldots+\beta nXn+\varepsilon \quad (3.2)$$

Where: (3.2)

$Y$ is the dependent variable.

$X1,X2,\ldots,Xn$ are the independent variables.

$\beta 0,\beta 1,\beta 2,\ldots,\beta n$ are the parameters of the model.

$\varepsilon$ is the error term, which is a random variable that adds noise to the linear relationship.

The parameters $\beta i$ represent the change in the average value of $Y$ due to a one-unit change in $Xi$ holding all other predictors fixed.

**Validation of model:** The trip generation and trip attraction models were trained and validated using a 70/30 data split. The training set comprised 70% of the data, used to develop the models, while the remaining 30% formed the testing set, used to evaluate their predictive performance. The R-squared ($R^2$) value, indicating the proportion of variance in the dependent variable explained by the independent variables, was used to measure model performance. The trip generation model achieved an $R^2$ of 0.69, and the trip attraction model had an $R^2$ of 0.65 on the testing data. These results demonstrate a strong predictive capability, indicating that the models are well-fitted and can reliably predict trip generation and attraction based on the selected variables.

| Model | $R^2$ (Model) | $R^2$ (Testing) | Data Split |
|---|---|---|---|
| Trip Generation | 0.67 | 0.69 | 70% / 30% |
| Trip Attraction | 0.67 | 0.65 | 70% / 30% |

Ultimately, using the specified explanatory variables, the models were developed to determine trip generation and trip attraction. This not only provides valuable insights but also paves the ground for the next step in the process.

Tables 3.7 and 3.8 show the parameters and the relationships between the dependent and independent variables for each of the two models In case of Trip production, the intercept is the expected mean value of Y when all X=0. The coefficient for 'Car Ownership' is 3.111.

**Table 3.7** Coefficients for trip production

| Variable | Coefficient | Standard Error | T Value |
|---|---|---|---|
| Population | 0.124 | 0.0146 | 4.5678 |
| Employment | 0.7851 | 0.987 | 7.981 |
| Car Ownership | 3.111 | 3.875 | 2.444 |
| Constant | 35.98 | | |
| $R^2$ | 0.67 | | |

**Table 3.8** Coefficients for trip attraction

| Variable | Coefficient | Standard Error | T Value |
|---|---|---|---|
| Population | 0.776 | 0.0455 | 7.987 |
| Employment | 0.134 | 0.654 | 6.456 |
| Population density | 0.998 | 0.,568 | 4.321 |
| Constant | 145.7 | | |
| $R^2$ | 0.5674 | | |

This means that for every one unit increase in 'Car Ownership', we expect an increase of approximately 3.111 units in trip production. It indicating that 'Car Ownership' is a statistically significant predictor of trip production. The coefficient for population is 0.124. This means that for every one unit increase in population, we expect an increase of approximately 0.124 units in trip production and population is also a statistically significant predictor of trip production. Meanwhile, the result shows that employment is also significant. The t-statistic is the coefficient divided by its standard error. It is used to test the hypothesis that the coefficient is different from 0. The p-value is the probability of observing a t-statistic as extreme as the one calculated (or more so) under the null hypothesis. The standard error is a measure of the variability in the estimate for the coefficient. It can be used to construct confidence intervals for the coefficient.

In case of Trip attraction, the coefficient for employment is 0.134. This means that for every one unit increase in employment, we expect an increase of approximately 0.134 units in trip attraction and employment is a statistically significant predictor of trip attraction. The coefficient for population is 0.776. This means that for every one unit increase in student, we expect an increase of approximately 0.42969 units in trip attraction. Similarly, population density is also significant.

After the model has been developed and fitted to the historical data, there is a mathematical equation that expresses the dependent variable as a function of the independent variables.

Multiple linear regression can be used to make forecasts for 2017 by inputting the values of the independent variables.

Figure 3.13 presents a graphical representation of the trip production and trip attraction across the 213 traffic zones in Kabul City. The figure provides an overview of how trip production and attraction are distributed across the city. This could offer insights into the flow of people within the city and highlight areas of high activity.

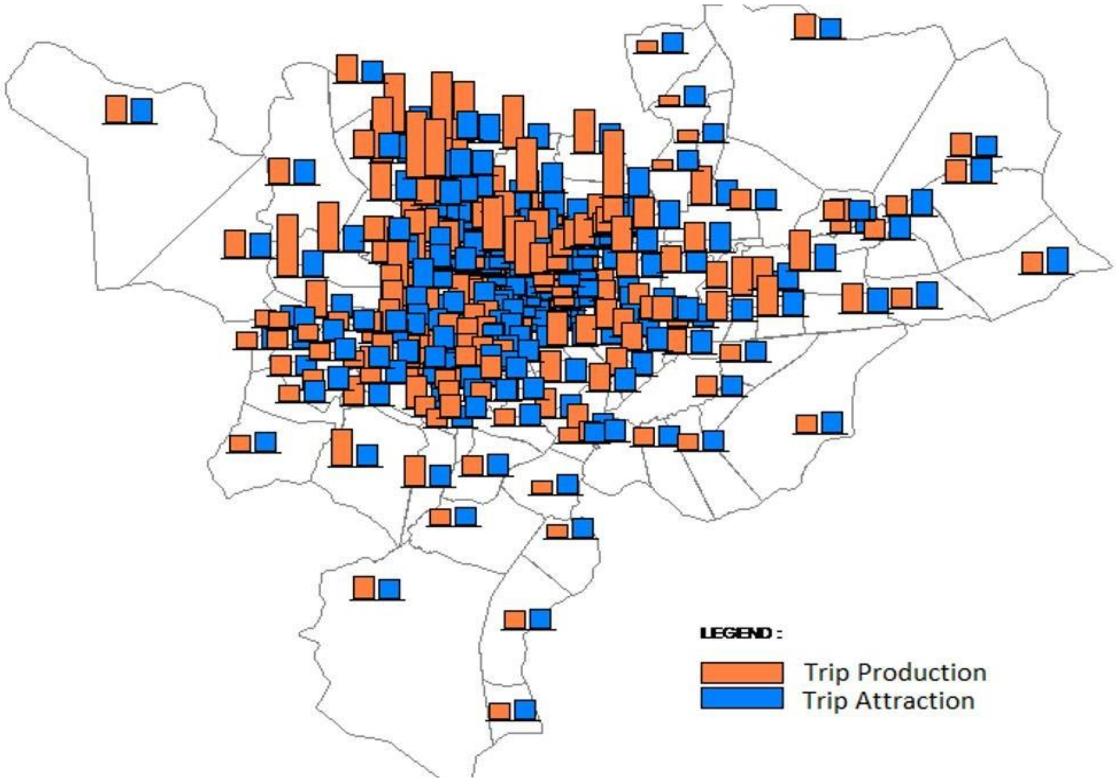



**Figure 3.13** Trip production and attraction in Kabul city

### 3.5 Analysing of Trip Distribution Model

Trip distribution represents the second phase in the Urban Transportation Demand Modelling (UTDM) process. This stage involves the decision-making process of a travellers determining their route from one traffic zone to another, guided by their specific journey's purpose. An origin traffic zone indicates the initial location where a traveller embarks, while the destination traffic zone represents the final point of the travel. Consequently, an origin-destination (O-D) matrix offers a complete view of trip distribution (Modi et al., 2011). A classic representation of an O-D matrix is shown in Table 3.8. Various models exist for examining trip distribution, inclusive of Growth Factor models, which include the Detroit model, Average factor model, Uniform model, Fratar model, Furness model and Synthetic models (Gravity model, Opportunity model, Intervening Opportunity model, and Competing Opportunity model). This research employs the Gravity model for discerning trip distribution across 213 traffic zones throughout Kabul city.

**Table 3.9** Notation of trip distribution matrix

| Traffic zone | 1 | 2 | 3 | … | j | … | n | $O_i$ |
|---|---|---|---|---|---|---|---|---|
| 1 | $T_{11}$ | $T_{12}$ | $T_{13}$ | … | $T_{1j}$ | … | $T_{1n}$ | $O_1$ |
| 2 | $T_{21}$ | $T_{22}$ | $T_{23}$ | … | $T_{2j}$ | … | $T_{2n}$ | $O_2$ |
| 3 | $T_{31}$ | $T_{32}$ | $T_{33}$ | … | $T_{3j}$ | … | $T_{3n}$ | $O_3$ |
| : | … | … | … | … | … | … | … | : |
| | $T_{i1}$ | $T_{i2}$ | $T_{i3}$ | ... | $T_{ij}$ | ... | $T_{in}$ | $O_i$ |
| : | … | … | … | … | … | ... | … | : |
| n | $T_{ni}$ | $T_{n2}$ | $T_{n3}$ | ... | $T_{nj}$ | ... | $T_{nn}$ | $O_n$ |
| Dj | $D_1$ | $D_2$ | $D_3$ | ... | $D_j$ | ... | $D_n$ | T |

Where, $D_j = \sum_i T_j$ $O_j = \sum_i T_{ij}$ $T = \sum_{ij} T_{ij}$

The Gravity Model is a popular method used in transportation planning to predict the flow of traffic between origins and destinations. This model is so named because it was inspired by Newton's Law of Gravity, which states that every particle in the universe attracts every other particle with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. Similarly, the Gravity Model in transportation planning states that the number of trips between two zones is directly proportional to the product of the attractiveness of the zones and inversely proportional to the travel cost (e.g., distance or time) between the zones.

$$T_{ij} = K \frac{G_i^{\alpha} A_j^{\beta}}{d_{ij}^{\gamma}} \quad (3.3)$$

where:

$T_{ij}$ is the number of trips between zone *i* (origin) and zone *j* (destination)

$G_i$ is the total number of trips originating from zone *i*

$A_j$ is the total number of trips destined for zone *j*

$d_{ij}$ is the distance between zone *i* and zone *j*

$\alpha$ and $\gamma$ are the exponents that represent the effect of the origin and destination attractiveness on the number of trips, respectively, $\beta$ is the distance exponent, which indicates the rate at which the number of trips decreases as the distance increases and $k$ is a proportionality constant. In this version of the model, $\beta$ will control how quickly the number of trips falls off as the distance increases. This model makes the assumption that the number of trips between two zones decreases as the distance between them increases, all else being equal. This assumption is often reasonable, but the exact relationship can depend on other factors, such as the availability and quality of transportation infrastructure, and these factors can be incorporated into the model if necessary. The necessary data for each traffic zone includes the number of trips originating from eachzone (*Oi*), the number of trips destined for each zone (*Dj*) and the travel distance between each pair of zones (*dij*). Equation 3.3 is applied to estimate trip distribution in 213 traffic zones, using STRADA software. Similar to the approach adopted in the trip generation model, the development of the distribution model necessitated the estimation of intercepts and coefficients. These estimates consider impedance, defined as travel distance. The derived values are presented in Table 3.10 offering a clear demonstration of the methodological consistency applied across the various stages of this transportation modelling study.

**Table 3.10** Coefficients for trip distribution in Kabul

| Var. Name | Coeff | Std Error | t value |
|---|---|---|---|
| α | -0.129 | 0.0654 | 13.612 |
| β | 0.742 | 0.0214 | 19.987 |
| γ | 0.208 | 0.0081 | 9.345 |
| k | 1.236 | | |
| Corr. Coefficient | 0.748 | | |

As a result, the calculated coefficients are incorporated into Equation 3.4, facilitating the achievement of the target results in terms of trip distribution, as represented in Equation 3.4. Subsequently, the Origin-Destination (OD) matrix is prepar.

$$T_{ij} = 1.236 \frac{G_i^{-.129} \; A_j^{0.742}}{d_{ij}^{0.0208}} \tag{3.4}$$

### 3.6 Analysing of Modal Split Model

In urban transportation planning, the third stage of travel demand modelling involves the consideration of modal split. This stage divides the total number of users across different modes of transport. Historically, the features of travellers were employed to ascertain mode choice after the initial stage of trip generation, utilizing either aggregate or disaggregate models. The choice of transport mode is integral to urban transportation demand modelling, particularly with regard to public transport usage, due to its lower emissions and more efficient road use compared to cars. Modal split is influenced by several factors, including user mode choice, which is contingent on user and mode characteristics, land-use, and population density (Santos et al., 2013). The model selection is a crucial process in urban transportation planning (NPTEL, 2007). There are various models to estimate mode choice, such as Trip-end modal split models, Trip-interchange modal split models, and aggregate and disaggregate models. If these models are based on zonal and inter-zonal information, they are considered aggregate. Conversely, if they are based on household or individual data, they are classified as disaggregate. In the case of aggregate models, they are applied following the gravity or distribution model. Three alternative functions are available: the Exponential function, Power function, and Logit curve function (Equations 3.5, 3.6, 3.7)

Table 3.11 Mode choice statistics

| | Mean | Median | Mode | Std Dev | Min | Max |
|---|---|---|---|---|---|---|
| All Mode | 117 | 105 | 85 | 50 | 21 | 273 |
| Non-Motorized | 15 | 13 | 4 | 7 | 4 | 41 |
| Motorized | 102 | 92 | 19 | 43 | 19 | 237 |
| Walk | 15 | 13 | 4 | 7 | 4 | 41 |
| PT | 62 | 56 | 10 | 27 | 10 | 153 |
| Car | 39 | 36 | 9 | 17 | 9 | 97 |
| Minibus | 37 | 33 | 5 | 18 | 5 | 98 |
| Microbus | 21 | 19 | 4 | 9 | 4 | 49 |
| Bus | 4 | 4 | 1 | 2 | 1 | 11 |
| Para-Transit | 58 | 53 | 9 | 25 | 9 | 142 |

$$y_{ij} = e^{b+\sum ax} \tag{3.5}$$

$$y_{ij} = b\prod \alpha \tag{3.6}$$

$$\mathrm{P} = 1 + \frac{1}{1+e^{b+\sum ax}} \tag{3.7}$$

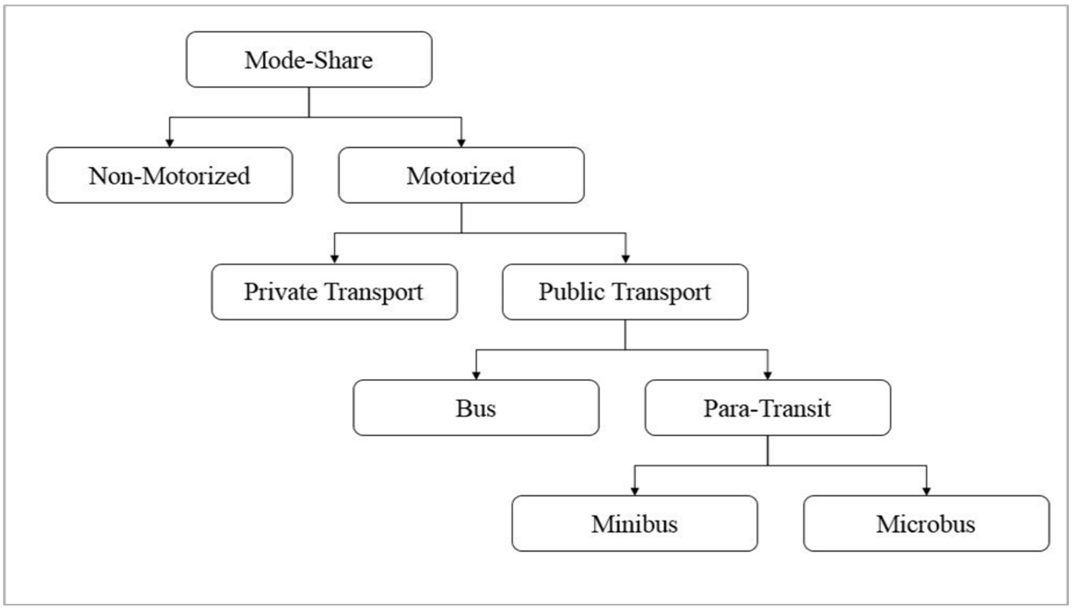



**Figure 3.14** Methodology for mode share in Kabul City

The Logit curve function (Equation 3.7) is used to estimate the mode share in Kabul city. At present, three types of urban transport modes are used in the city: walking, public transport (including buses, minibuses, and microbuses), and private transport (including cars and motorcycles). This study considers the mode share among walking, public transport, and private transport to discern residents' behaviour regarding mode choice based on average travel time in Kabul city. Travel time or impedance is estimated from the minimum path distance between traffic zones (in km). Initially, the trips are categorized into motorized and non-motorized. Then, they are further divided into private and public transport. Public transport users are further segmented into para-transit and bus users, and para-transit users are subsequently divided into minibus and microbus users. The average travel time for each transport mode is estimated by dividing the road distance by the existing transport mode's speed. Figure 3.14 outlines these processes.

In alignment with the processes of trip generation and trip distribution, the estimation of mode share within the city also necessitates the modelling of coefficients. This modelling has been executed using the STRAD software, a tool specifically designed for transport demand modelling. Table 3.11 presents the calculated coefficient rates for each existing mode of transportation currently in use in Kabul city. This data serves as a crucial foundation for comprehensively understanding and predicting the transportation demands and preferences of the city's residents, thereby informing more effective and sustainable urban planning strategies.

**Table 3.12** Coefficients for modal split in Kabul city

| Var Name | Coeff | Std Error | t value |
|---|---|---|---|
| Travel time- motorized | 0.3411 | 0.0023 | 4.256 |
| Travel time- non-motorized | 0.5678 | 0.0134 | 2.345 |
| Constant | 113 | 0 | 0 |
| Corr. Coefficient | 0.55 | 0 | 0 |
| | | | |
| Travel time-PT | 0.13644 | 0.00092 | 1.7024 |
| Travel time-Car | 0.22712 | 0.00536 | 0.938 |
| Constant | 45.2 | 0 | 0 |
| Corr. Coefficient | 0.22 | 0 | 0 |
| | | | |
| Trave time bus | 0.23877 | 0.00161 | 2.9792 |
| Trave time-paratransit | 0.39746 | 0.00938 | 1.6415 |
| Constant | 79.1 | 0 | 0 |
| Corr. Coefficient | 0.385 | 0 | 0 |
| | | | |
| Trave time-minibus | 1.137 | 0.007666667 | 14.18667 |
| Trave time-microbus | 1.892667 | 0.044666667 | 7.816667 |
| Constant | 376.6667 | 0 | 0 |
| Corr. Coefficient | 0.183333 3 | 0 | 0 |

The correlation coefficient rates for the existing modes have been determined to be satisfactory for the development of the models. Ultimately, Table 3.11 presents the results of the mode share across the 22 districts of Kabul city. In addition to this, the mode share results concerning the 213 traffic zones are depicted in Figures 3.15 and 3.16. Furthermore, the detailed mode choice in 213 zones indicates in Appendix (Table A 1). In the context of transportation models, especially concerning mode share (the percentage of travelers using a particular type of transportation), the correlation coefficient might demonstrate how closely related certain variables are to these outcomes. For instance, variables might include:

**Table 3.13** Mode share in 22 districts of Kabul city.

| Dis No | Non - Motorized | Motorized | Public Transport | Private Transport | Bus | Para Transit | Minibus | Microbus |
|---|---|---|---|---|---|---|---|---|
| **1** | 21771 | 195938 | 113209 | 82729 | 7019 | 106190 | 63170 | 43019 |
| **2** | 24778 | 200480 | 117134 | 83345 | 7379 | 109755 | 66415 | 43340 |
| **3** | 26861 | 217333 | 129423 | 87910 | 8283 | 121140 | 74548 | 46592 |
| **4** | 38411 | 307285 | 185069 | 122215 | 12029 | 173040 | 108265 | 64774 |
| **5** | 28459 | 206325 | 128064 | 78261 | 8580 | 119483 | 77222 | 42261 |
| **6** | 26660 | 195503 | 119968 | 75535 | 7918 | 112050 | 71261 | 40789 |
| **7** | 47888 | 271365 | 178782 | 92583 | 12693 | 166088 | 114241 | 51847 |
| **8** | 37540 | 230602 | 147478 | 83124 | 10176 | 137302 | 91584 | 45718 |
| **9** | 25724 | 231516 | 123475 | 108041 | 7162 | 116314 | 64454 | 51860 |
| **10** | 58608 | 266994 | 188849 | 78144 | 14353 | 174497 | 129173 | 45324 |
| **11** | 47911 | 271498 | 178869 | 92629 | 12700 | 166169 | 114297 | 51872 |
| **12** | 20061 | 147114 | 90275 | 56840 | 5958 | 84316 | 53623 | 30693 |
| **13** | 24235 | 160321 | 102531 | 57790 | 7075 | 95456 | 63672 | 31785 |
| **14** | 6613 | 40623 | 25035 | 15588 | 1677 | 23358 | 15096 | 8262 |
| **15** | 22591 | 228419 | 120485 | 107934 | 6868 | 113617 | 61809 | 51808 |
| **16** | 22352 | 110445 | 74945 | 35500 | 5471 | 69474 | 49239 | 20235 |
| **17** | 9435 | 76337 | 45459 | 30878 | 2909 | 42550 | 26184 | 16365 |
| **18** | 13431 | 23509 | 12855 | 10653 | 765 | 12090 | 6887 | 5203 |
| **19** | 4482 | 29994 | 17928 | 12067 | 1165 | 16762 | 10488 | 6275 |
| **20** | 6424 | 64950 | 33546 | 31405 | 1879 | 31667 | 16907 | 14760 |
| **21** | 14421 | 105757 | 62493 | 43264 | 4000 | 58493 | 35996 | 22497 |
| **22** | 4360 | 39242 | 20929 | 18313 | 1214 | 19715 | 10925 | 8790 |
| **Total** | **533015** | **3621548** | **2216799** | **1404749** | **147273** | **2069526** | **1325457** | **744069** |

This table appears to detail the usage of various modes of transport across different districts (Dis No). Modes of transport include Non-Motorized, Motorized, Public Transport, Private Transport, Bus, Para Transit, Minibus, and Microbus.

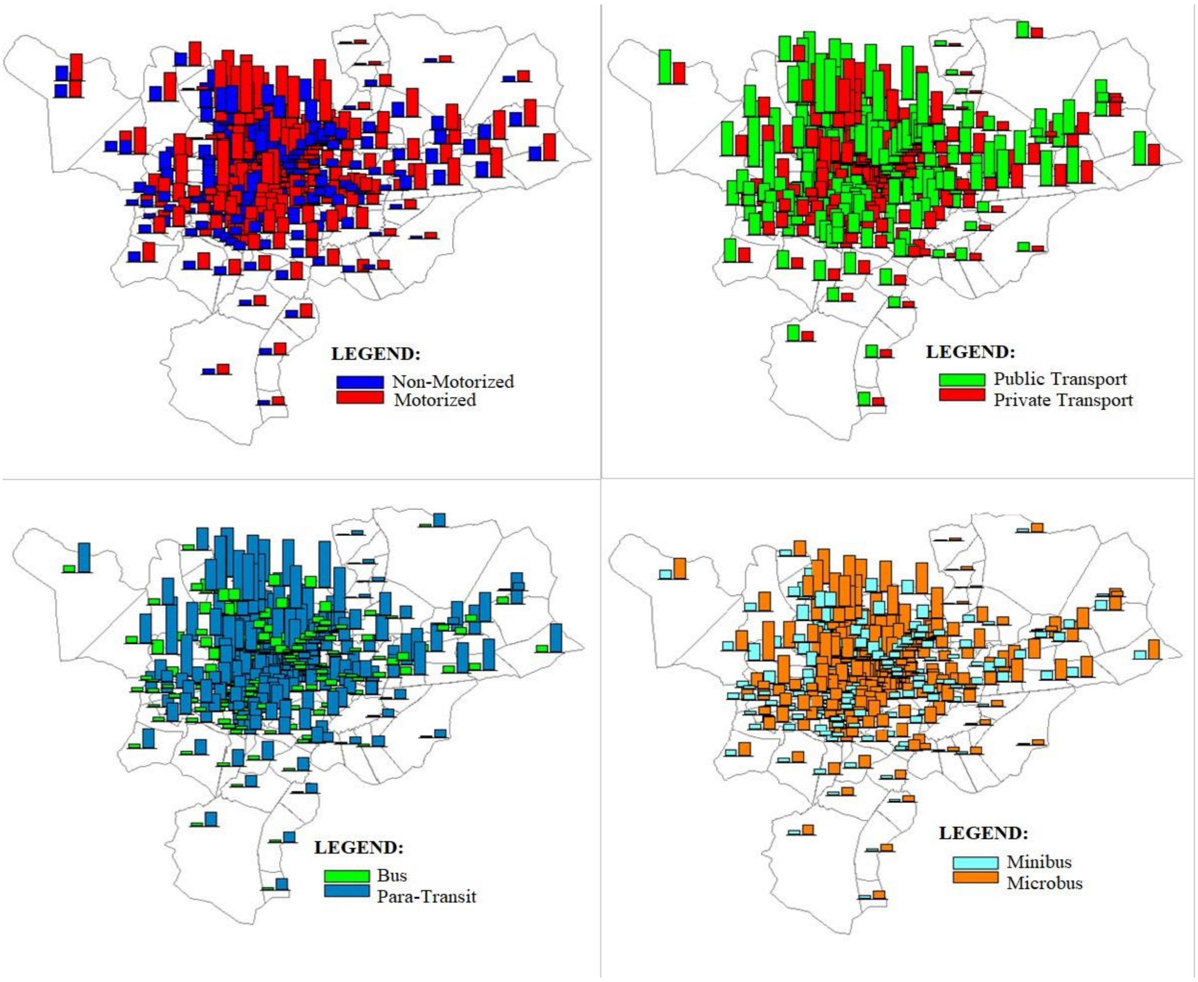



**Figure 3.15** Mode share model in Kabul city

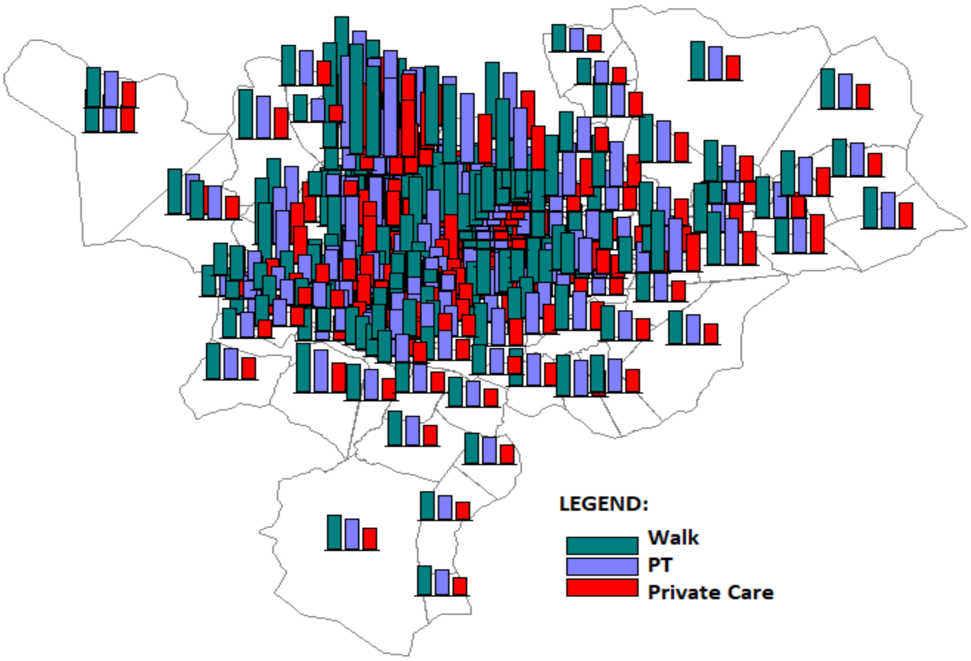



**Figure 3.16** Trip by three traffic modes in Kabul city

## 3.7 Trip Assignment

In Trip assignment creates the final phase of the Urban Transportation Demand Model (UTDM) processes. After determining the volume of trip generation within each traffic zone, distributing trips from the origin to the destination zone, and determining the modal split, travellers assess the most suitable route for zone-to-zone travel. Various traffic assignment models exist, including the All-or-Nothing, Diversion, and Capacity Restraint models. This study focuses on the All-or-Nothing method to designate the route for each trip. The All-or-Nothing method aligns with the minimum path algorithm. A central assumption of this approach is the absence of congestion impacts and the belief that all drivers have a uniform perception of attributes when selecting a route. The road network plays a pivotal role in the traffic assignment model. This study represents the distinct segments of the network using two fundamental descriptors: links and nodes (as depicted in Figure 3.17). Specifically, the 2013 traffic zone in Kabul city comprises 389 links and 297 nodes.

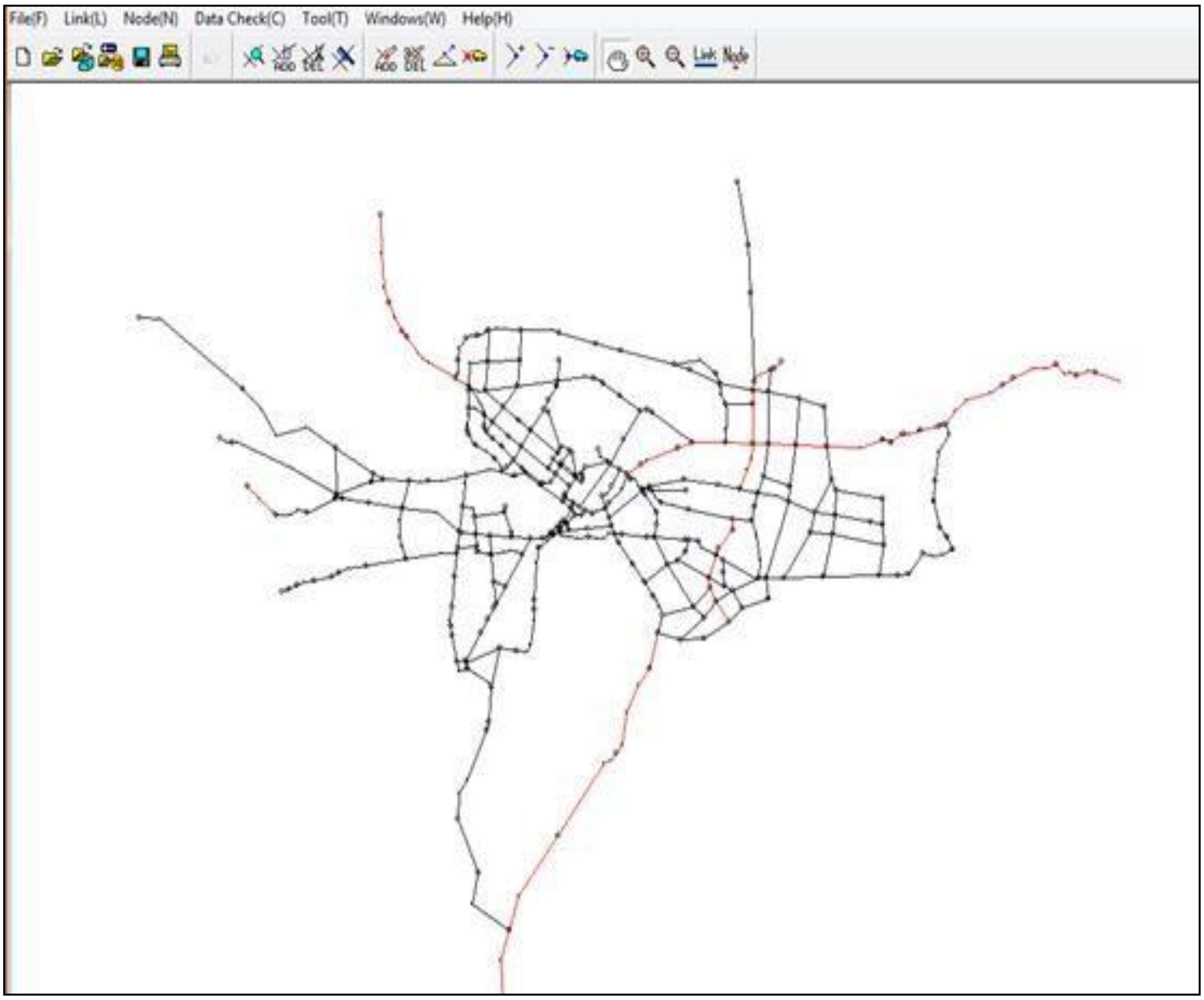



**Figure 3.17** Kabul city PT road network by links and nodes

The Kabul network under consideration was systematically formulated using various parameters, namely: link name, node name, link distance, link velocity, link capacity, and link direction. The data for this network was precisely obtained from the Kabul Municipality. Subsequently, by utilizing the Kabul Road network, assignment parameters, and the OD (Origin-Destination) trip matrix specific to the public transport mode, a trip assignment model was constructed. This model was executed using the STRADA software, incorporating the 2017 travel demand data. In this approach, the Person Trip Origin Destination (PTOD) data is initially transformed into Vehicle Trip Origin Destination data. Ultimately, the Passenger Car Unit (PCU) values are derived. The outcomes of this assignment are illustrated in Figure 3.18.

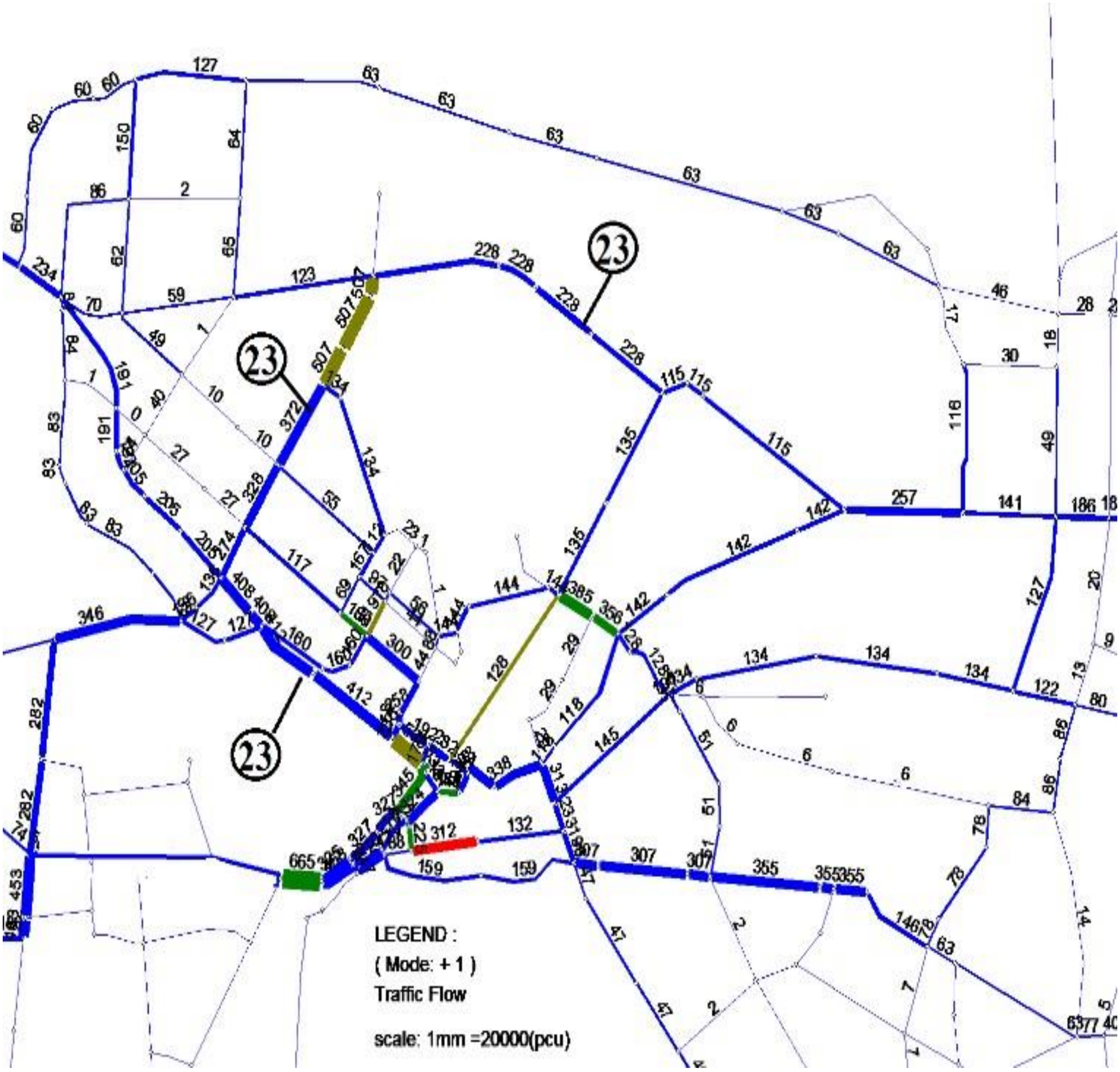



**Figure 3.18** Trip assignment result in Kabul city

The findings from the trip assignment highlight that the travel demand for Public Transport (PT) on route 23 surpasses that of other routes. Drawing from the conclusions of the feasibility study, it becomes evident that the width of the route, which measures 50 meters with three lanes in each direction, is suitably configured to accommodate a BRT system. Given these considerations, route 23 emerges as a prime candidate for the implementation of the BRT system, spanning a length of 10 kilometres. This proposed BRT corridor, stretching from Kabul airport to the centre of the city, is shown in Figure 3.19.

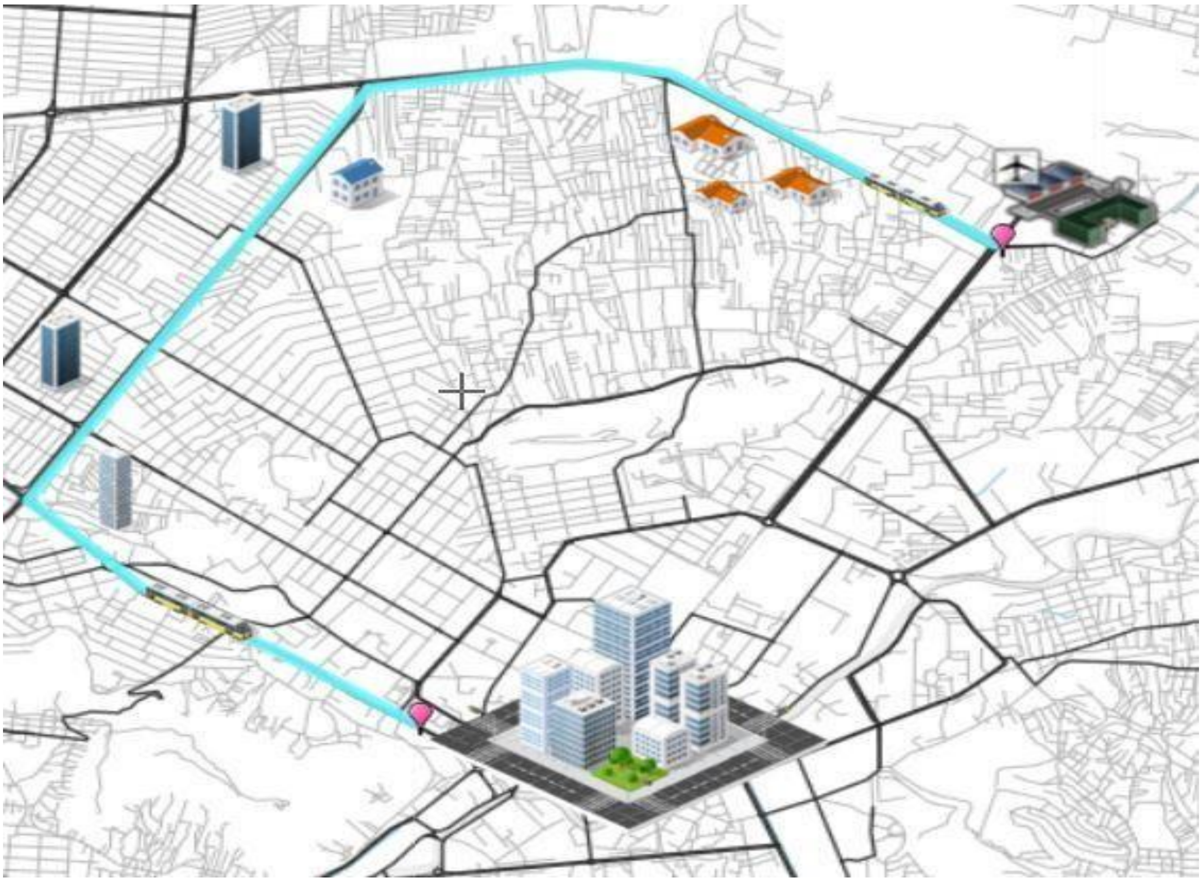


**Figure 3.19** Purposed BRT system based on high travel demand in Kabul city

For development of trip assignment for Kabul city, only PT is considered. However, Kabul lacks a formal PT network with specific stations and terminals, as it has not had regular PT services for a long time.

The network depicted in Figure 3.19 represents PT network, By limiting the assignment to PT, the study aimed to provide a detailed understanding of this sector's dynamics, which is crucial for planning and improving public transport services in Kabul..

### 3.8 Summary

The Urban Travel Demand Modelling study for Kabul employed a range of analytical tools to interpret the city's transportation patterns. Through multiple linear regression, fundamental factors like population, employment, car ownership and density were identified as major contributors to trip generation. A significant trend was observed with most travel directed from suburban areas to the Central Business District (CBD). The Gravity Model was involved in mapping trip distributions across 213 traffic zones, revealing the city's primary travel routes.

The study examined the modal split in Kabul and found that many residents prefer low-capacity vehicles. Using the Logit curve function, the study got a clearer picture of these travel choices. Since the low-capacity vehicles are increasing and to be consider as a major threat to the urban transportation system. It is required to introduce MRT transit system with high technology in order to reduce low-capacity vehicles. Therefore, this research has conducted trip assignment to understand BRT possibilities in the city in terms of travel demand. For bus routes, the All-or-Nothing model identified route 23 as a top choice for a new BRT system. This route would link Kabul airport with the city centre. Overall, this research provides insights to improve transportation planning in Kabul.

# CHAPTER 4

# MODAL SHIFT ANALYSIS FOR BUS RAPID TRANSIT SYSTEM

## 4.1 General

A modal shift happens when one type of transport offers clear benefits over others, encouraging people to change their travel habits. In some growing cities, especially in developing countries, there is a rise in the use of smaller vehicles like motorcycles. This section focuses on applying the Ordinal Logistic Regression (OLR) model combined with Stated Preference (SP) data to understand the preferences of current users of autos, shared taxis, and private cars. The objective is to pinpoint the main factors that could motivate a shift to the upcoming BRT system. Aspects such as travel time, cost, wait time, time taken to walk to the station, the gap between stations, route and station design, availability of air conditioning, the purpose of the trip, possession of a driving license, car ownership, gender, and age are considered potential influences on the decision to opt for BRT. Subsequent sections will explore the study's location,methodology, data collection methods, and a summarized overview of the results.

## 4.2 Study Area

This research focuses on Jalalabad as the study location. Spanning an area of 127.3 square kilometres and 573m above sea level, Jalalabad is Afghanistan's fifth-largest city. With a population of 381,655, it comprises several districts (Figure 4.1) and Street Network Disconnectedness Index shown in Figure 4.2. Districts 1, 2, 3, 4, and 5 show a higher population density than the remaining districts. Many residential structures here are built without prior planning. The City Centre ridges with markets, employment hubs, business establishments, and shopping areas (Figure 4.3), making it more attractive to inhabitants than other districts. Several key highways intersect the city Centre, such as the Jalalabad-Kabul, Jalalabad-Kunar, Jalalabad-Chaperhar, and Jalalabad-Khowgyani highways. A gap exists in comprehensive and efficient public transport for the city's residents. Most rely on low-capacity vehicles (LCVs) like autos and shared taxis for transportation. The spread of private vehicles adds to the city's transportation challenges, leading to congestion, accidents, and pollution. Nevertheless, a 2017 survey by the Jalalabad Municipality (Transportation report) suggests that the city's road networks possess adequate capacity to accommodate the travel demands of its inhabitants. Jalalabad's road system is categorized into five types: highway, arterial, secondary, community,

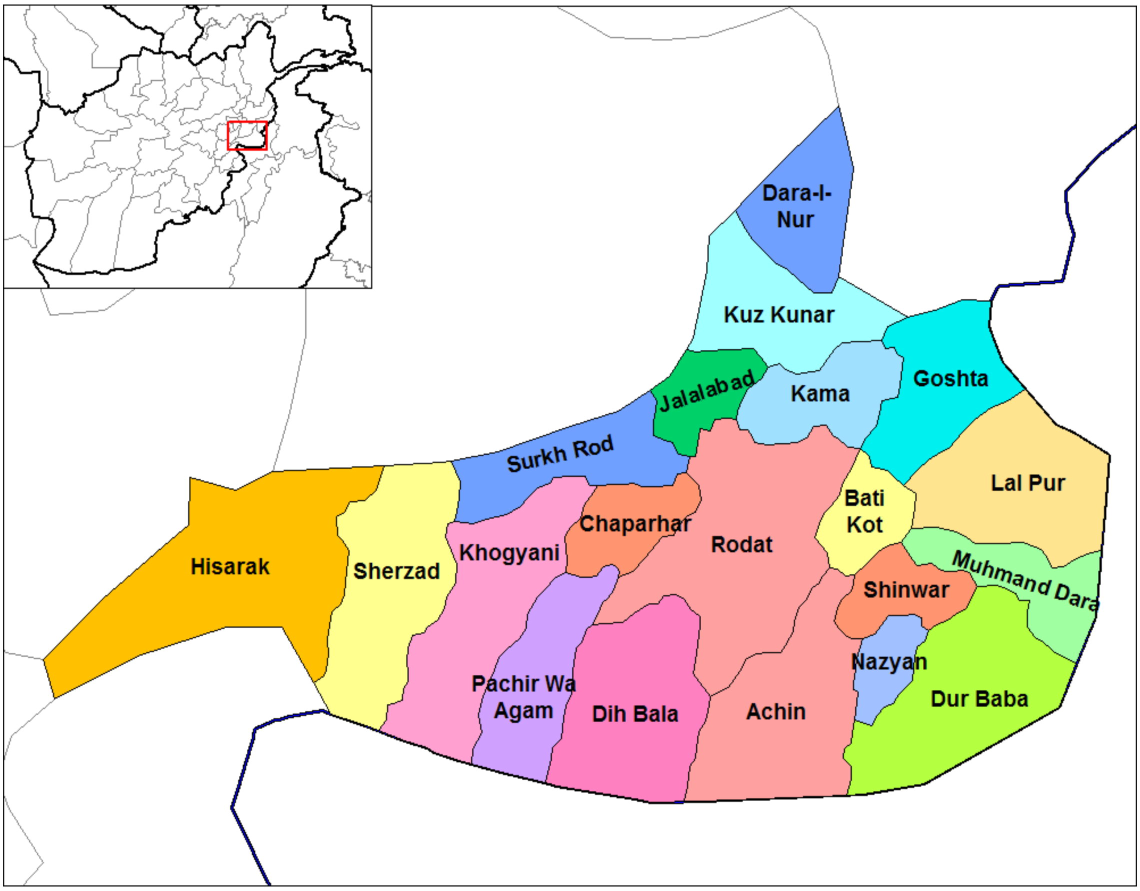



**Figure 4.1** District map of the city (Source: GIS)

and other. Jalalabad is a busy city in eastern Afghanistan that has a mix of old and new elements in its streets and buildings. The roads are often full of different kinds of transport like bicycles, motorbikes, and small three-wheeled vehicles called auto-rickshaws. These vehicles are popular because they can easily move through the busy and narrow streets. Buses and shared taxis are also common and give people an affordable way to get around the city Public transport is an important part of life in Jalalabad.

Buses usually follow set routes and are a cheap way for people to travel longer distances across the city. Shared taxis and auto-rickshaws provide more flexible options, and they can take people more directly to where they need to go.

The city itself has a variety of buildings, with some being very old and traditional, while others are newer. The roads connect different areas like shopping markets, homes, and government buildings. There's a lively feeling in Jalalabad with the busy streets, shops, and people moving about. As the city grows and changes, finding ways to manage the busy roads while keeping the special history and feel of the place is an ongoing task.

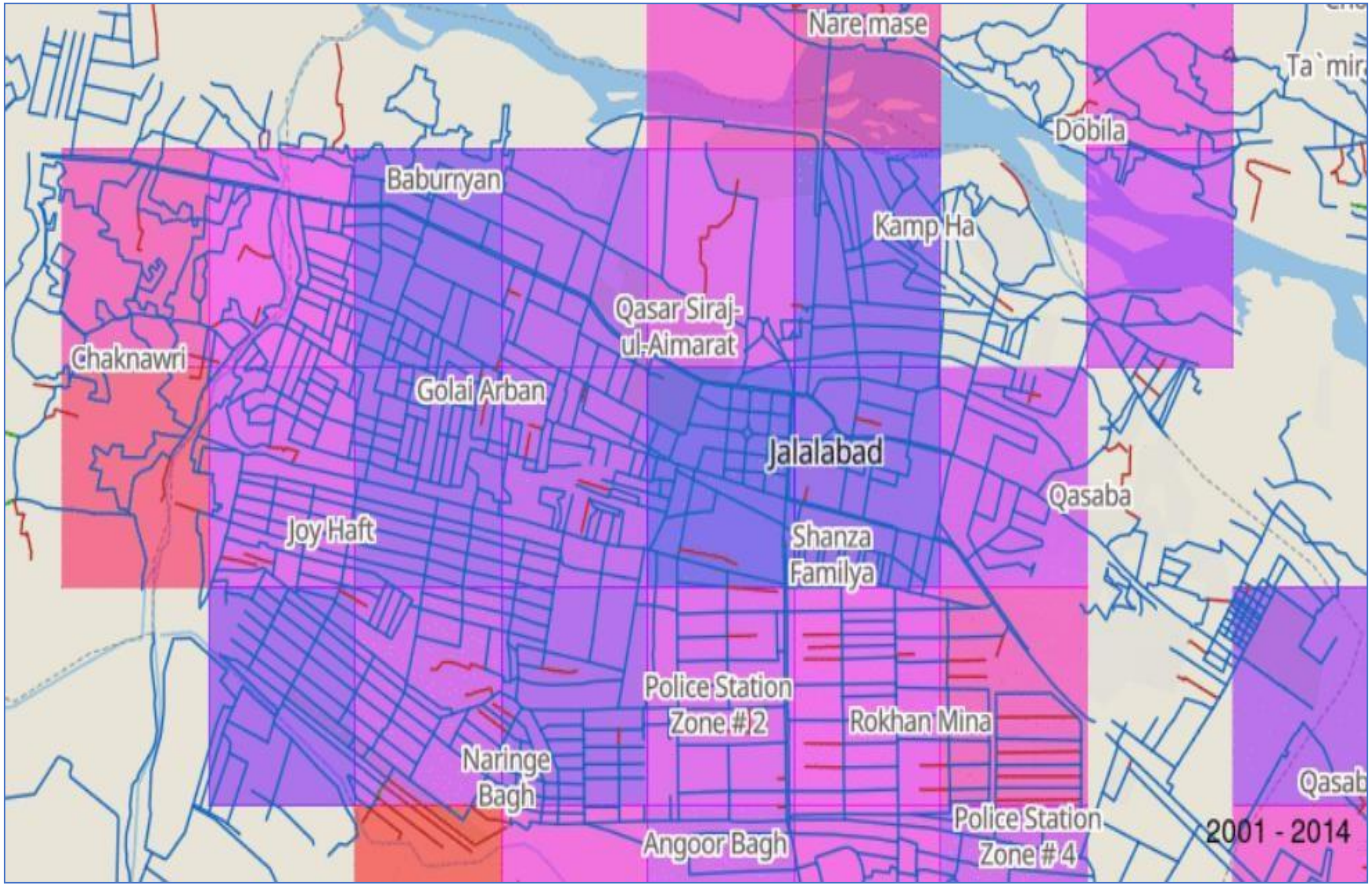



**Figure 4.2** Street Network Disconnectedness Index (Source: GIS)

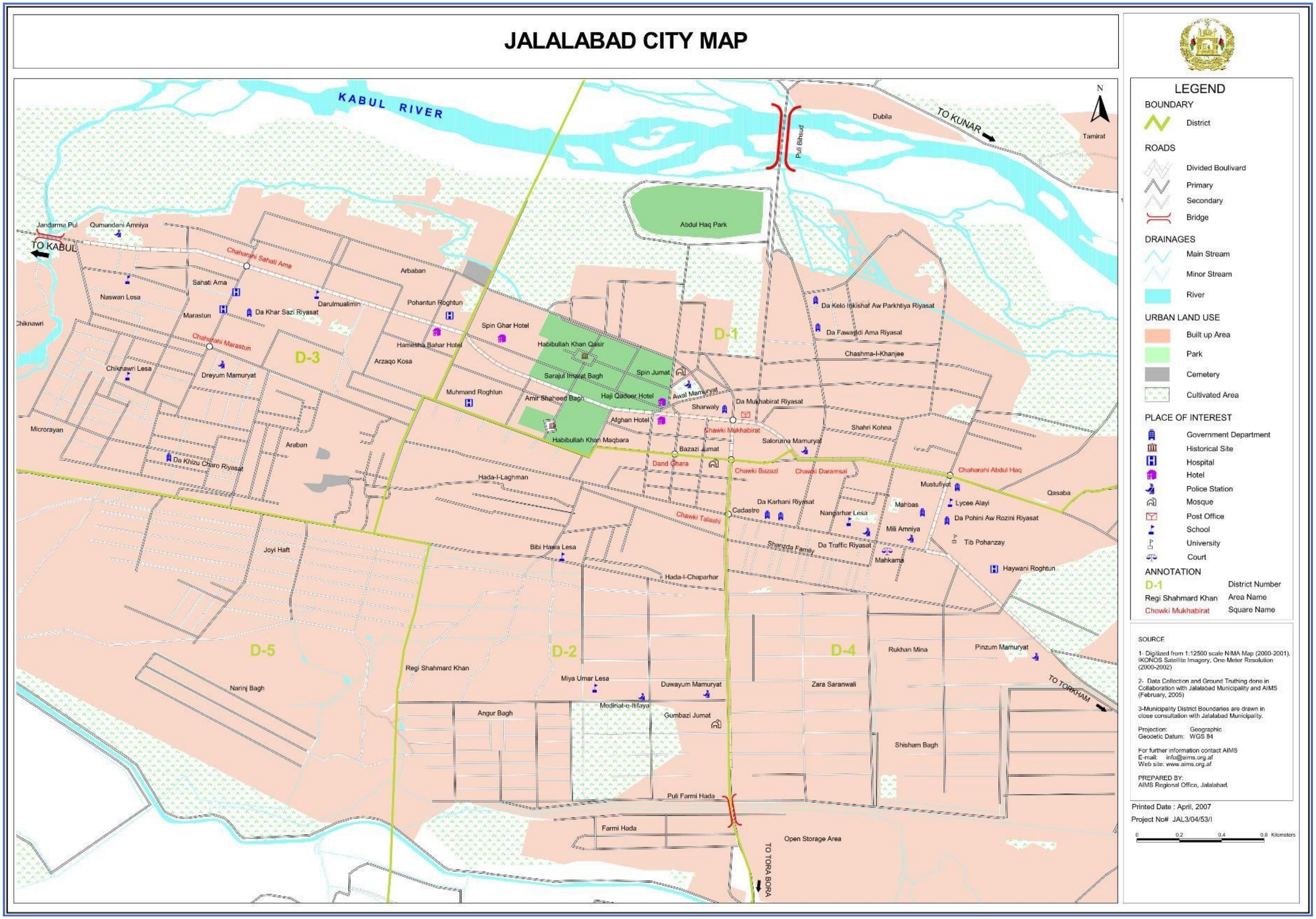



**Figure 4.3** Jalalabad land-use map (USAID 20017)

### 4.3Modal Shift Approaches

This study employs the Ordinal Logistic Regression (OLR) model to investigate the key factors influencing an individual's shift from current transportation modes such as rickshaws, taxis, and cars to the proposed BRT system. Before using the OLR model, a Stated Preference experiment (SP) is conducted to gauge the influence of various variables.

Drawing from local conditions and previous studies, several factors, including individual social characteristics, travel attributes, and proposed BRT features, are identified as potential influencers for the model's development. The subsequent sections investigate deeper into each step, clarifying the approach taken to meet the objective. Figure 4.4 provides a detailed flowchart defining the methodology, providing a clear graphical representation of the progressive processes and steps.

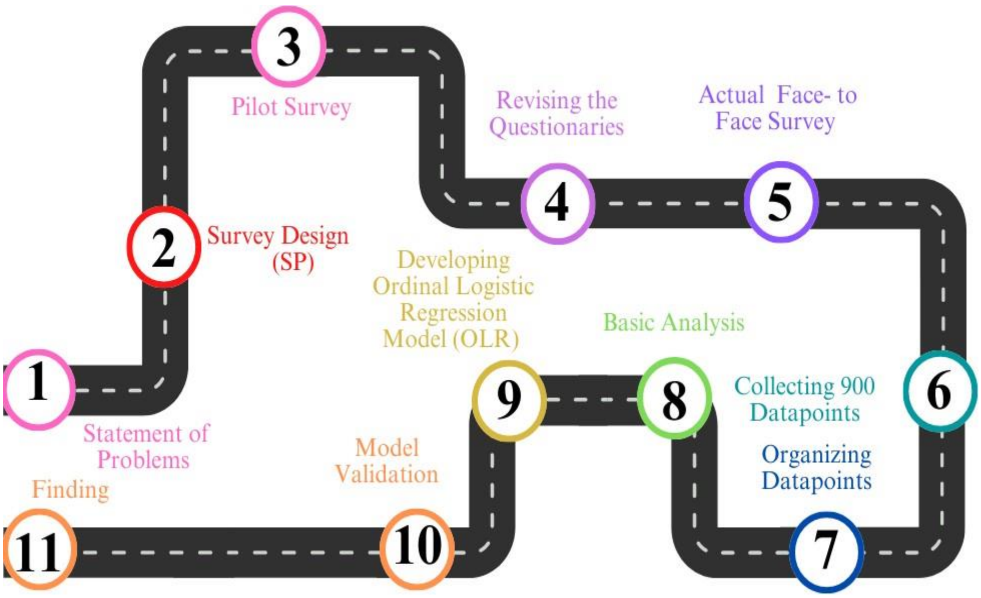



**Figure 4.4** Methodology offering a visual representation of the processes

#### 4.3.1 Examining Travel Mode Shifts Through Data Collection

The SP surveys are a key tool in research, as highlighted by Szolnoki G and colleagues in 2013. These surveys help researchers explore specific problems by breaking them down into parts for easy study.

There are three main sections in an SP survey. The first part looks at different personal details like age, gender, and whether a person owns a car. The second part asks about things related to individual travel, such as travel purpose and whether they have a driving license.

The final section presents distinct BRT scenarios, visualized in Appendix Figure A1. When crafting the last section, concerning BRT scenarios, a total of eight attributes were established, each varying in levels. Specifically, three attributes—travel time, travel cost, and waiting time—are designed with four levels, while the subsequent five attributes—walking time to the station, availability of air conditioning, stop spacing, corridor type, and station type—are characterized by two levels, as elaborated in Table 4.1 and illustrated in Figure 4.5.

The reasoning behind choosing these particular parameters is explained in the subsequent text: Travel Time (TT): Seeing time as a valuable, limited resource is essential since it's akin to currency. The amount of time spent on travel directly affects people's well-being, joy, and economic status.

Travel Cost (TC): In a nation like Afghanistan, which has one of the lowest GDPs, the impact of any expense, including travel cost, is profound on the citizens' quality of life, making it a crucial element to examine.

Air Conditioning in Public Transport (PT): The inclusion of air conditioning in PT systems is tied closely to the local weather conditions.

Corridor Type: The choice of a BRT corridor can substantially affect the performance of the BRT system.

Distance Between Stations: Given the predominantly unplanned housing in Jalalabad city, meticulous planning is necessary when deciding the location and spacing of stations.

Station Type: BRT system designs commonly involve protected and non-protected stations, with the type being dependent on local conditions.

Employing all attributes and levels in a full factorial design would lead to an unmanageable number of questions (43 x 25 = 1075), making field application impractical. Therefore, an orthogonal fractional factorial design was used to meld characteristics and attribute levels, resulting in 16 questions (BRT Scenarios) being incorporated, summarizing all attributes and levels (refer to Table 4.2). levels (Table 4.2).

**Table 4.1** Monitored characteristics and levels of attributes considered for the SP Survey

| Scenario | Attributes | Level of Attributes |
|---|---|---|
| BRT | Travel cost (TC) | 10 Afg, 20 Afg, 30 Afg, 40 Afg |
| | Travel time (TT) | 35 min, 45 min, 55 min, 60 min |
| | Waiting Time (WT) | 5 min, 8 min, 10 min, 15 min |
| | Walking time to station (WTS) | 5 min, 10 min |
| | Air-condition (AC) | Yes, No |
| | Station type (ST) | Protected (P), Non-Protected (N-P) |
| | Distance between stations (SD) | 500 m - 800 m, 800 m -1000 m |
| | Corridor type (CT) | Dedicated (D), Mixed (M) |

**Table 4.2** Presented BRT scenarios to participants

| BRT Scenarios | TC (Afg) | TT (min) | WT (min) | SD (m) | WTS (min) | ST | AC | CT |
|---|---|---|---|---|---|---|---|---|
| **1** | 30 | 55 | 5 | 500 - 800 | 10 | P | Yes | M |
| **2** | 40 | 35 | 15 | 800 -1000 | 10 | N-P | Yes | M |
| **3** | 40 | 45 | 10 | 500 - 800 | 10 | P | No | D |
| **4** | 10 | 35 | 5 | 500 - 800 | 5 | N-P | No | M |
| **5** | 20 | 35 | 8 | 500 - 800 | 10 | P | Yes | D |
| **6** | 10 | 55 | 10 | 800 -1000 | 10 | P | Yes | M |
| **7** | 30 | 60 | 8 | 800 -1000 | 10 | N-P | No | M |
| **8** | 30 | 35 | 10 | 800 -1000 | 5 | N-P | No | D |
| **9** | 10 | 45 | 8 | 800 -1000 | 5 | N-P | Yes | M |
| **10** | 30 | 45 | 15 | 500 - 800 | 5 | P | Yes | D |
| **11** | 40 | 55 | 8 | 500 - 800 | 5 | N-P | No | D |
| **12** | 20 | 55 | 15 | 800 -1000 | 5 | P | No | M |
| **13** | 20 | 45 | 5 | 800 -1000 | 10 | N-P | No | D |
| **14** | 10 | 60 | 15 | 500 - 800 | 10 | P | No | D |
| **15** | 40 | 60 | 5 | 800 -1000 | 5 | P | Yes | D |
| **16** | 20 | 60 | 10 | 500 - 800 | 5 | N-P | Yes | M |

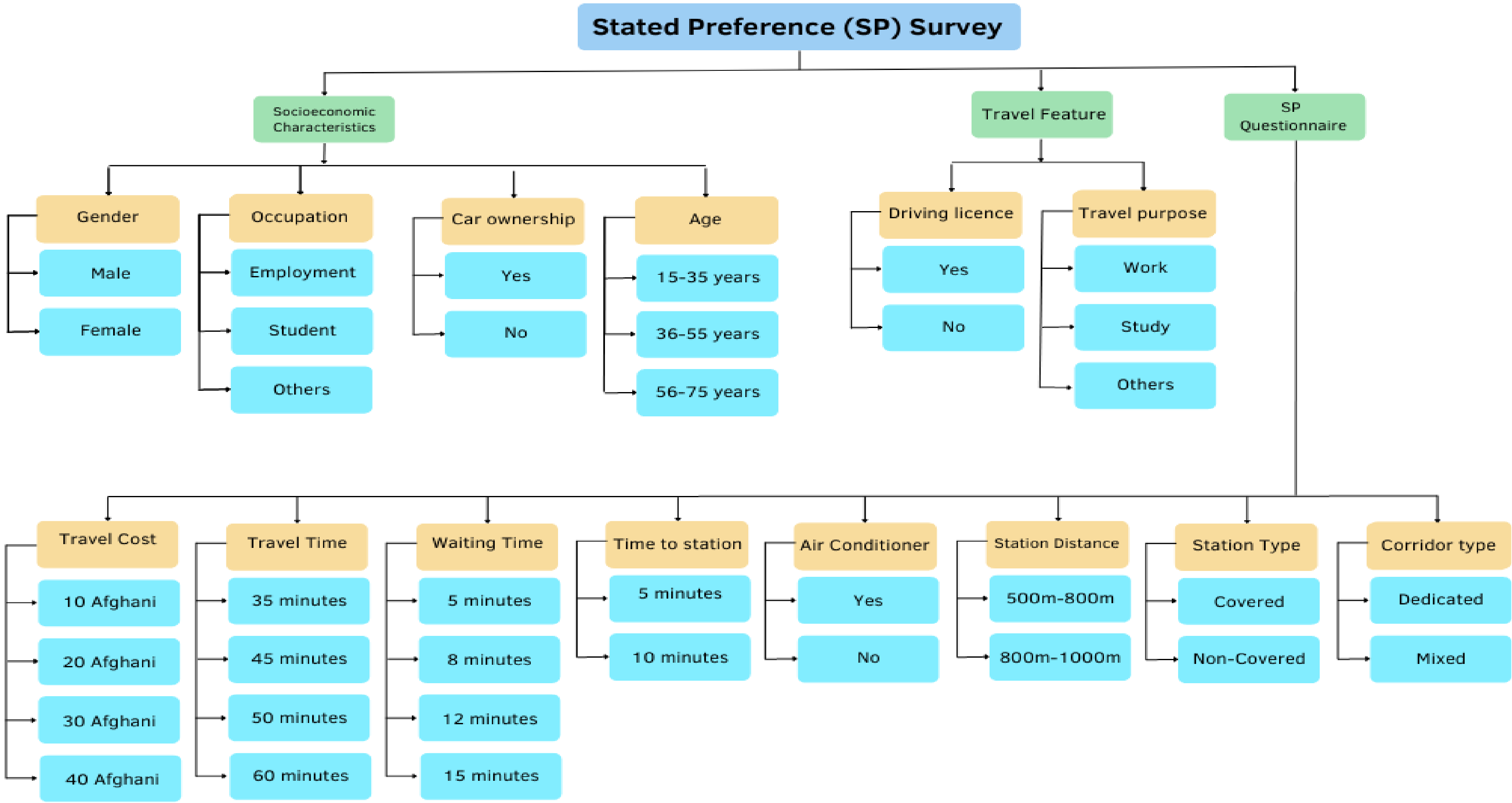



**Figure 4.5** Collected data through the SP survey

SP experiment, questionnaires fall into three categories: choice, rating, and ranking. This study emphasizes the ranking method to glean additional insights into user preferences. The questionnaires utilize a four-tier satisfaction scale, ranging from "highly dissatisfied" to "highly satisfied." Every scenario is showcased to each specific mode user, who is then prompted to gauge the scenarios based on the provided satisfaction levels, while considering various BRT scenarios shaped by different attribute combinations that define BRT services. A blend of survey methods, including face-to-face, online, postal, and telephone, were deployed to collect data. Notably, face-to-face surveys bring several key benefits, such as structured interaction, personal engagement, and control within the context of the survey.

A pilot survey plays a crucial role in acquiring essential data while simultaneously minimizing unneeded exertion for both the researchers and the participants. Prior to undertaking the principal face-to-face interactions, an initial survey was carried out, accumulating 70 data points. Insights gathered demonstrated a prevalent reluctance among participants to reveal their consistent income.

As a result, adjustments were made to the survey forms, retaining only the car ownership variable and discarding the income variable. In this research, foundational information was extracted from the Jalalabad Master Plan. For the study's analysis, a primary Stated Preference (SP) survey was conducted in person at several travel-inducing locations, including educational institutions, transport terminals, retail centres, and government/non-government offices, as well as throughout the designated BRT pathway (10 km).

Figure 4.6 provides a visual representation of the data collection points (Bagrami, Zakir Abad, Qaser, Chawck, Shinwari, Angoor Bagh), accumulating a comprehensive total of 900 data points. This data was garnered from users of various transportation modes, namely, share-taxi, rickshaw, and private car, with each mode contributing 300 data points.

During the on-site survey, participants were chosen at random to uphold the precision of the data. Specific preferences, such as the cost and time of travel, wait and walk times, stop spacing, station and corridor types, and the presence of air conditioning for the anticipated BRT system, were compiled through Stated Preference (SP) queries. Table 4.3 outlines the data acquired, encapsulating aspects like gender, car possession, driving license status, age bracket, and travel intent. Figure 4.7 elucidates the connection between the likelihood of a modal shift and attributes, including travel duration, expense, and wait time, while Table 4.4 showcases the interrelations amongst the variables.

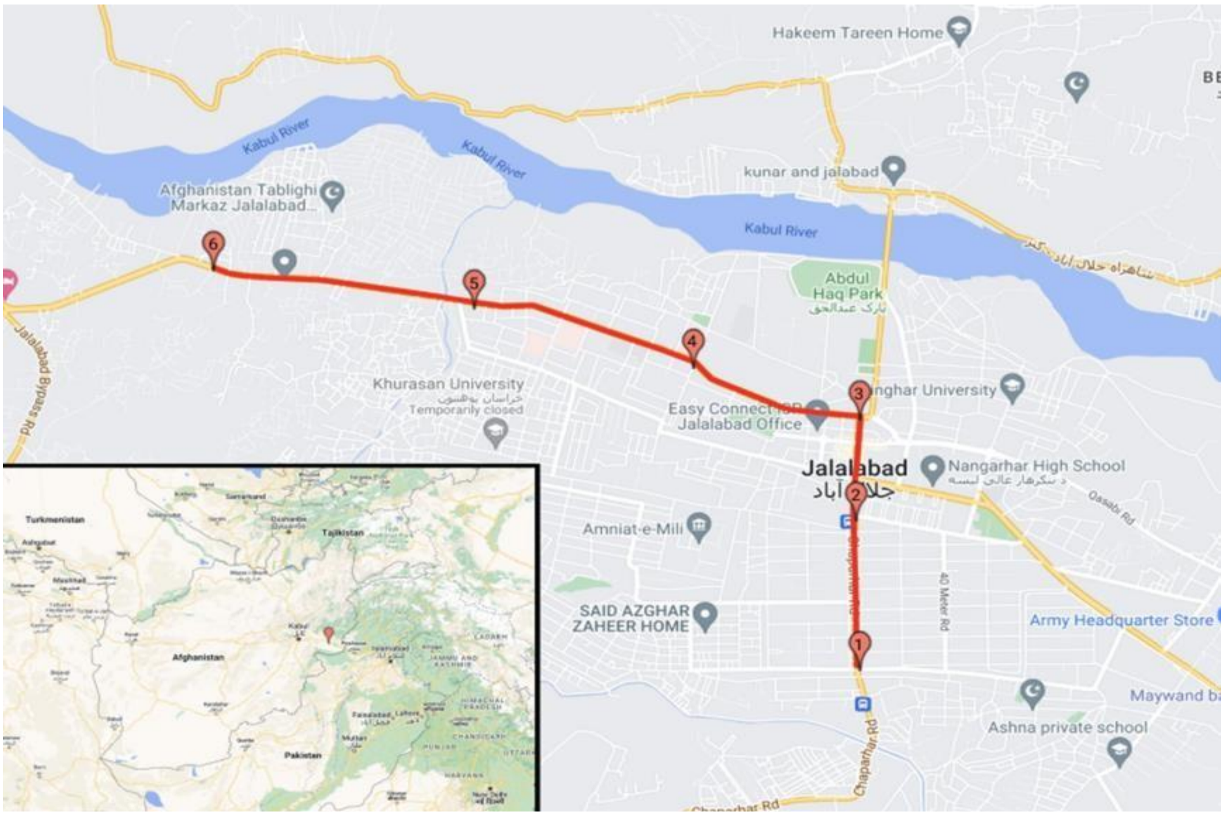



**Figure 4.6** Planned ten-kilometre BRT route and interview sites in Jalalabad city

**Table 4.3** Summary of gathered data and categorical variables

| Variable | Description | Mode | | | Total |
|---|---|---|---|---|---|
| | | Auto | Share-Taxi | Car | |
| Gender | Female (1) | 95 | 106 | 16 | 217 |
| | Male (0) | 205 | 199 | 279 | 683 |
| Car Ownership | Yes (1) | 16 | 32 | 268 | 332 |
| | No (0) | 284 | 268 | 16 | 568 |
| Driving License | Yes (1) | 16 | 64 | 284 | 364 |
| | No (0) | 284 | 236 | 16 | 536 |
| Age | 15-35 (0) | 186 | 101 | 103 | 390 |
| | 36-55 (1) | 98 | 183 | 147 | 428 |
| | 55-75 (2) | 16 | 16 | 50 | 82 |
| Trip Purpose | Work (0) | 176 | 192 | 109 | 477 |
| | Study (1) | 43 | 50 | 55 | 148 |
| | Others (2) | 81 | 58 | 136 | 275 |
| Total Sample | | 300 | 300 | 300 | 900 |

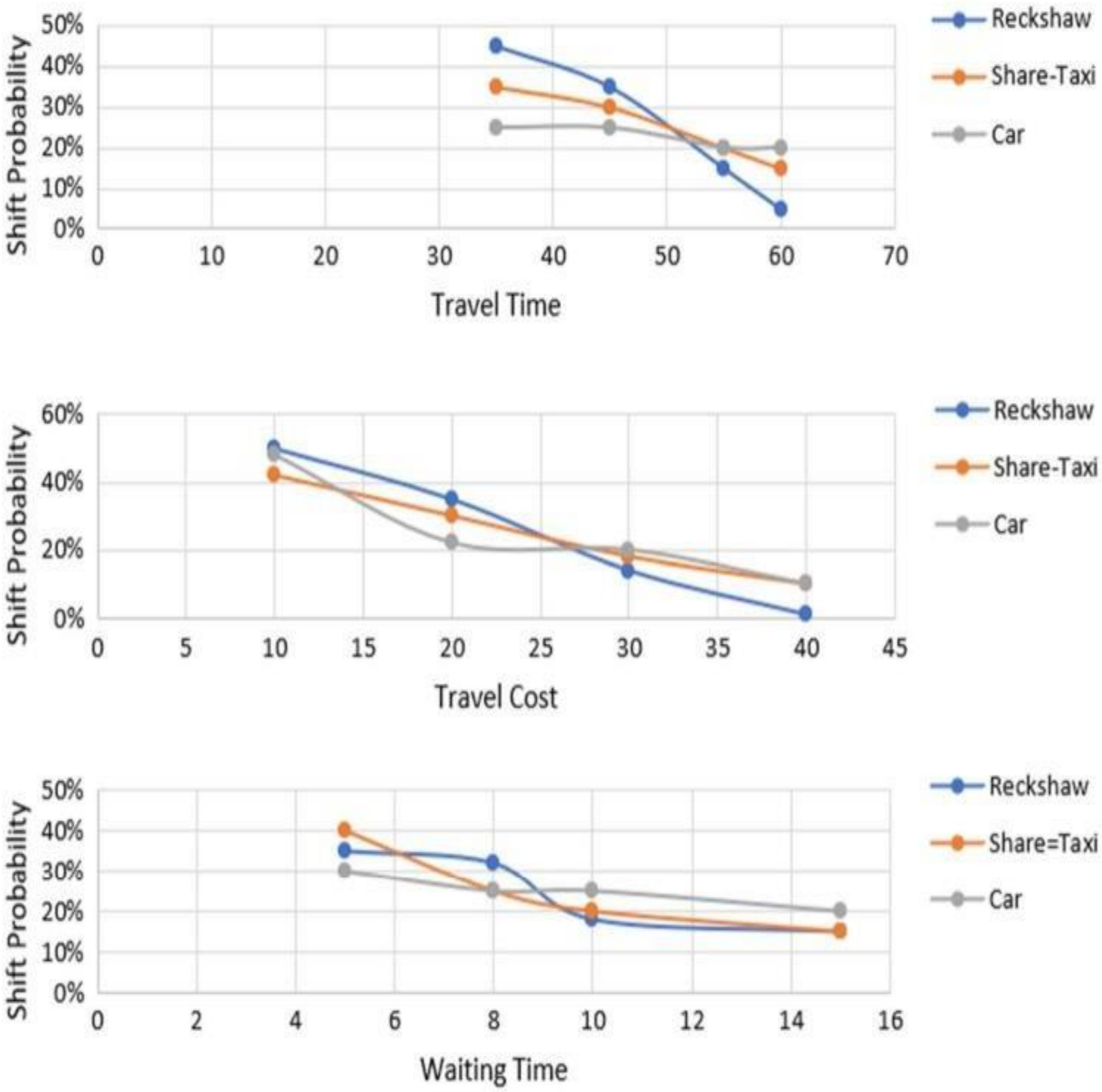



**Figure 4.7** Association among mode shift possibility and attributes

**Table 4.4** Association among predictor variables

| | TC | TT | WT | SD | WTS | ST | AC | CT |
|---|---|---|---|---|---|---|---|---|
| TC | 1 | | | | | | | |
| TT | 0.33 | 1 | | | | | | |
| WT | 0.19 | 0.09 | 1 | | | | | |
| SD | -0.05 | 0.21 | 0.19 | 1 | | | | |
| WTS | 0.06 | 0.09 | 0.28 | 0.22 | 1 | | | |
| ST | 0.33 | 0.20 | 0.20 | 0.24 | -0.03 | 1 | | |
| AC | -0.06 | 0.13 | 0.19 | 0.38 | 0.21 | -0.25 | 1 | |
| CT | 0.33 | 0.19 | 0.12 | -0.26 | -0.06 | 0.21 | 0.19 | 1 |

### 4.3.2 Preliminary Analysis

Figures 4.8, 4.9 and 4.10 highlight the potential for transition among users of rickshaws, cars, and share-taxis, respectively, towards the proposed Bus Rapid Transit (BRT) system. Meanwhile, Figure 4.11 illustrates the cumulative shift probability among existing mode users. Per Table 4.2, respondents were presented with 16 scenarios, and their feedback was categorized into four levels of interest: highly dissatisfied, dissatisfied, satisfied, and highly satisfied. Figure 4.8 portrays the preferences of current rickshaw users in relation to the proposed BRT system along a specific route in Jalalabad city, revealing that scenarios 4 and 9 emerge as the most appealing, while scenarios 2, 3, and 6 lack allure. Data depicted in Figure 4.9 indicates a notable portion of private car users express interest in transitioning to the BRT system, with a pronounced satisfaction in scenarios 4 and 5. Similarly, Figure 4.10 reflects the disposition of share-taxi users towards BRT scenarios, demonstrating a high satisfaction predominantly with scenarios 4 and 9. In conclusion, Figure 4.11 provides a snapshot into the overall likelihood of transition to the BRT system for current transport mode users in Jalalabad city. Preliminary analysis of the BRT scenarios in Table 4.2 revealed that the likelihood of users shifting to the BRT system was impacted by factors such as travel duration, cost, and waiting time, among others.

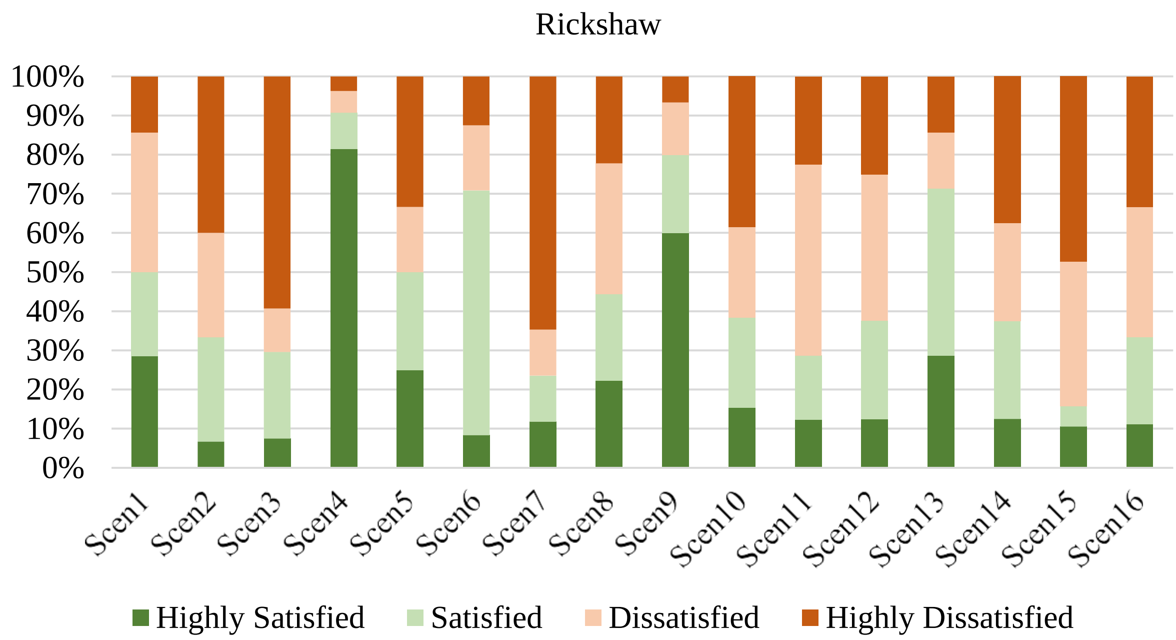



**Figure 4.8** Shift likelihood to planned transit system for Auto vehicle operators

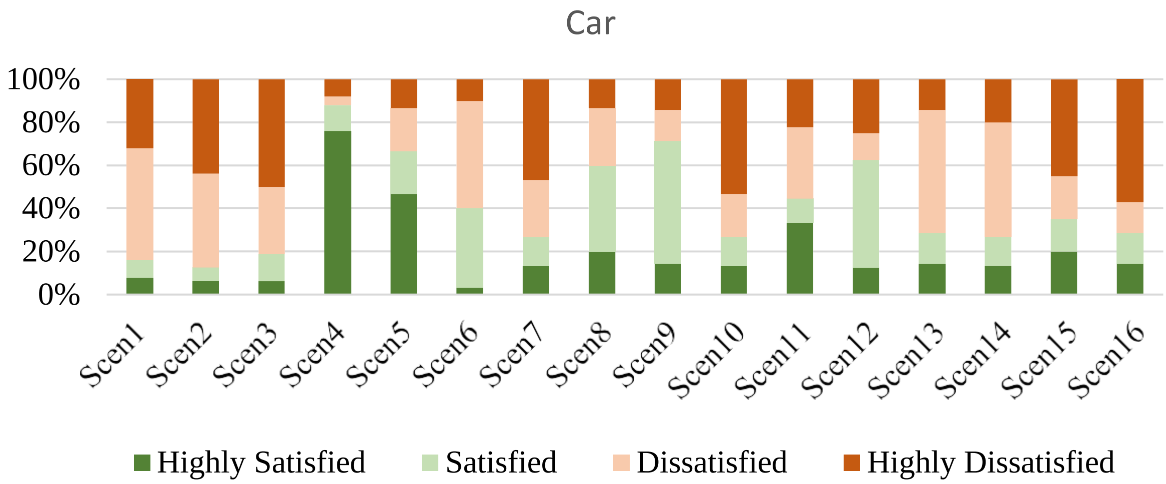



**Figure 4.9** Transition likelihood to the envisioned BRT system for automobile users

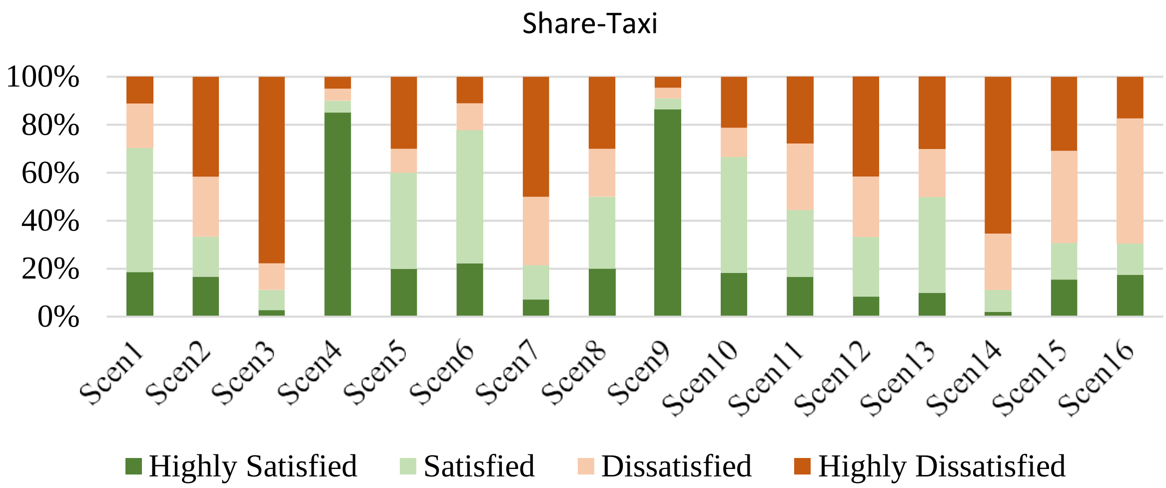



**Figure 4.10** Likelihood of transition to the suggested BRT system among shared-taxi patrons

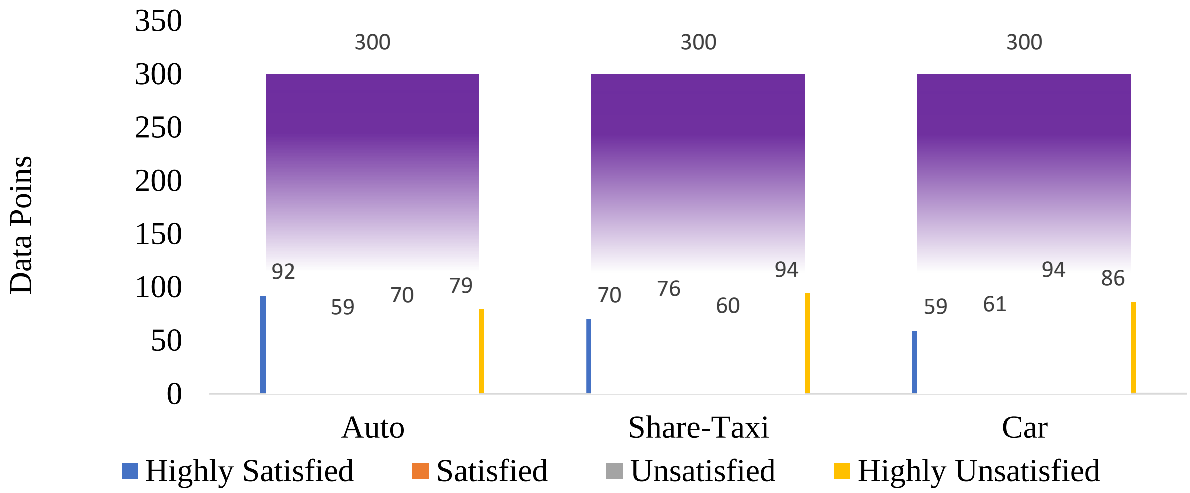



**Figure 4.11** Complete transition likelihood towards the suggested BRT framework

Initial analysis indicated a strong relationship between modal shift and specific attributes. For instance, an increasing in travel time tends to reduce the shift towards the BRT system. In contrast, when costs are lowered, the BRT system typically garners more interest. Nonetheless, this assertion lacks a robust statistical basis. Therefore, this study deploys an Ordered Logit Regression (OLR) examination on the Stated Preference (SP) dataset to identify which variable(s) significantly influence the modal shift. The progression of the OLR model is depicted in Figure 4.12.

### 4.3.3 Ordinal Logistic Regression

Ordinal Logistic Regression (OLR) represents a specific type of statistical analysis, introduced briefly in this discussion. Regression analysis, commonly utilized in market research, allows for an exploration of relationships between variables. Viewing a regression model as a predictive tool facilitates understanding of the relationship between a dependent variable, referred to as "Y", and an independent variable, termed "X".

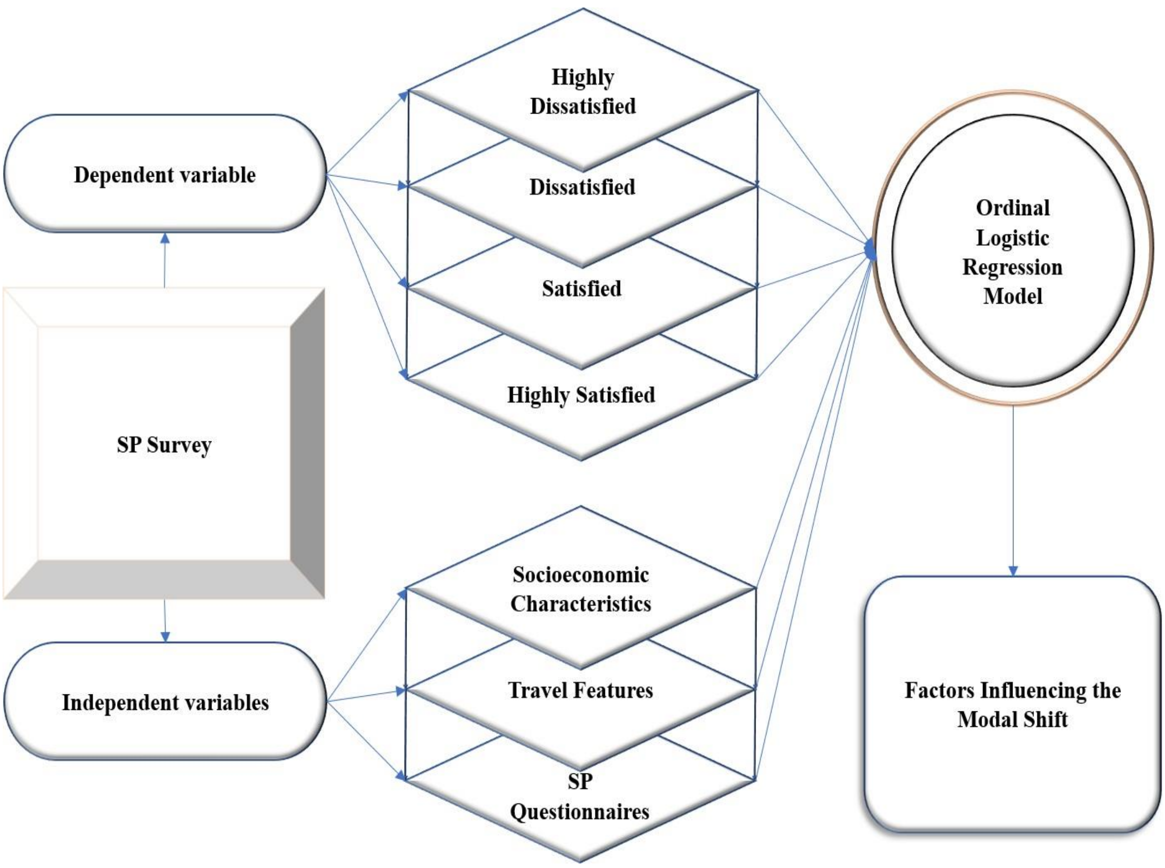



**Figure 4.12** Process of the OLR model

The OLR serves as a subset of the logit regression model and finds utility when the dependent variable is categorical, possessing a clear order and exceeding two levels. Equation 4.1 becomes instrumental in estimating the model, with SPSS software

$$:-\ln \frac{1}{p_n(i)-1} = \sum_{n=1}^{\infty} \beta \, X_{kin} \tag{4.1}$$

Where:

$Pn$ represents the Probability

$\beta$ is the Coefficient, and

$X$ denotes the variable

Calculations for the left side of this model can involve different probabilities. In this study, the Ordered Logistic Regression (OLR) model became a tool for estimating the mode shift data gathered via the Stated Preference (SP) experiment. Utilizing the OLR model necessitates consideration of specific assumptions:The dependent variables are categorized.

1. One or more factors are either continuous, categorical, or ordinal.
2. There is no multicollinearity among the variables.

The dataset utilized in the study conforms to assumptions 1 and 2. Evaluation of the correlation among variables ensured the fulfilment of assumption 3. Results of this evaluation are presented in Table 4.4, confirming the absence of potent multicollinearity between variables.

### 4.3.4 Development of Shift Model

The data collected, comprising 300 data points each for auto, share-taxi, and private car categories, was bifurcated into two segments. 200 data points for each mode underwent random selection for model development, with the residual 100 samples per mode dedicated to model validation objectives. To enhance the estimation process, every independent variable received a coding of 0, 1, or 2, demonstrated in Table 4.3. Dependent variables received coding as well: 1 corresponds to highly dissatisfied, 2 to dissatisfied, 3 to satisfied, and 4 to highly satisfied. The development of the model encompasses determining parameters' rates to enhance data feasibility under the model specification. Consequently, some parameters may be regarded as insignificant and excised from the model. The Likelihood Ratio Index (ρ2), defining the goodness of fit for model estimation, illustrates the precision with which the model can predict mode choice behaviour (Satiennam et al., 2016). The Likelihood Ratio Index is assessed by Equation 4.2.

$$\rho^2 = 1 - \frac{LL(\beta)}{LL\,(0)} \tag{4.2}$$

Where:

*LL* ($\beta$) = Final Likelihood

*LL* (0) = Initial Likelihood.

The OLR model was developed for each mode's users individually. Tables 4.5, 4.6, and 4.7 present the results for observed mode users regarding modal shift behaviour. The first model was developed using 200 data points for each mode's users and the Likelihood Ratio Index (ρ2) was estimated in the model validation process. Secondly, a similar process was employed using 100 data points. Both Likelihood Ratio Indexes were compared for closeness. The results of the model validation are presented in Table 4.8.

**Table 4.5** OLR model estimation for rickshaw users about BRT mode shift

| Variable | Coefficient | Std. Error | Wald | P-value |
|---|---|---|---|---|
| Travel Cost | -0.081 | 0.012 | 42.856 | 0.000 |
| Travel Time | -0.069 | 0.016 | 18.022 | 0.000 |
| Waiting Time | -0.148 | 0.045 | 10.532 | 0.001 |
| Walking Time | 0.803 | 0.294 | 7.464 | 0.006 |
| Initial LL | | -254.316 | | |
| Final LL | | -148.204 | | |
| LL ratio index ($p^2$) | | 0.41 | | |
| N | | 200 | | |

**Table 4.6** OLR model estimation for share-taxi users about BRT mode shift

| Variable | Coefficient | Std. Error | Wald | P-value |
|---|---|---|---|---|
| Travel Cost | -0.047 | 0.013 | 13.967 | 0.000 |
| Travel Time | -0.048 | 0.015 | 9.782 | 0.002 |
| Waiting Time | -0.151 | 0.039 | 14.813 | 0.000 |
| Walking Time | 0.590 | 0.283 | 4.343 | 0.037 |
| Gender | -1.265 | 0.334 | 14.381 | 0.000 |
| AC | -0.611 | 0.309 | 3.902 | 0.048 |
| Initial LL | | -225.216 | | |
| Final LL | | -147.762 | | |
| LL ratio Index ($p^2$) | | 0.343 | | |
| N | | 200 | | |

**Table 4.7** OLR model estimation for car users about BRT mode shift

| Variable | Coefficient | Std. Error | Wald | p-value |
|---|---|---|---|---|
| Travel Cost | -0.060 | 0.012 | 24.668 | 0.000 |
| Travel Time | -0.062 | 0.016 | 14.691 | 0.000 |
| Waiting Time | -0.121 | 0.042 | 8.491 | 0.004 |
| Walking Time | 1.028 | 0.343 | 8.976 | 0.003 |
| AC | -0.673 | 0.281 | 5.716 | 0.017 |
| Purpose | -1.003 | 0.414 | 5.856 | 0.016 |
| Initial LL | | -206.195 | | |
| Final LL | | -158.21 | | |
| LL ratio Index ($p^2$) | | 0.23 | | |
| N | | 200 | | |

**Table 4.8** Model validation outcomes

| Model development with 200 data points | | Equation | Model development with 100 data points | |
|---|---|---|---|---|
| Auto | | | | |
| Initial LL | -254.3 | $\rho^2 = 1 - \frac{LL(\beta)}{LL\,(0)}$ | Initial LL | -149.4 |
| Final LL | -148.2 | | Initial LL | -100.4 |
| ρ2 | 0.41 | | ρ2 | 0.40 |
| Share-Taxi | | | | |
| Initial LL | -225.2 | $\rho^2 = 1 - \frac{LL(\beta)}{LL\,(0)}$ | Initial LL | -171.9 |
| Final LL | -147.7 | | Initial LL | -114.3 |
| ρ2 | 0.34 | | ρ2 | 0.34 |
| Private Car | | | | |
| Initial LL | -206.1 | $\rho^2 = 1 - \frac{LL(\beta)}{LL\,(0)}$ | Initial LL | -149.9 |
| Final LL | -158.2 | | Initial LL | -114.8 |
| ρ2 | 0.23 | | ρ2 | 0.23 |

Table 4.5 gives us key data from the OLR model for rickshaw riders. Before we dig into how different factors influence people's decisions to switch transportation modes, it’s vitalto check if our model can predict accurately. So, two different likelihood figures werecompared, and a special number, called a ratio index (ρ2), was figured out. Past research tells us that a ρ2 value of 0.41 in Table 4.5 means the model fits well for auto users. This number confirms that certain variables, like how much and how long people travel, can reliably predictthings in the OLR model for auto users.

The data showed that travel cost, duration, and waiting times, which all have negative signs, are crucial ($P \leq 0.05$). Walking time, with a positive sign, is also notable. Meanwhile, various other factors, such as distance between stations and age, weren’t impactful and were left out of the model. So, the findings suggest that lowering travel and waiting times may convince more rickshaw riders to use BRT systems. However, if the walk to BRT stations gets longer, fewer people might switch.

Table 4.6 provides a snapshot of the model developed for share-taxi users. The results include a high likelihood ratio index (ρ2=0.343), indicating a reliable model. Moreover, the P-values for several variables (like travel cost and time, waiting time, walking time to the station, air conditioning, and gender) are below 0.05. This tells us that all these factors in Table 4.6 are meaningful with a 95% confidence level.

For share-taxi users, if travel costs, times, and waiting times go down (noted by negative signs), more people might be drawn to the new BRT system. Conversely, if walking time to the station is reduced, user interest goes up.

Additionally, a negative sign for air conditioning suggests share-taxi users might prefer a BRT system with cooling, probably due to Jalalabad city's intense heat and lack of air conditioning in most share-taxis. Lastly, the negative sign for gender suggests women might be more willing than men to switch to the BRT system, perhaps perceiving it as a safer travel option than share-taxis.

Table 4.7 presents the estimation of the OLR model for private car users. Both -2 likelihood values (Initial and Final) were compared, and consequently, the value of the likelihood ratio index was generated ($\rho2$=0.23), which provides an approximately acceptable value. However, concerning the likelihood ratio index for car users, the model appears weaker than the models for auto and share-taxi users in terms of model fit. The given P-values in Table 4.7 show that travel cost, travel time, waiting time, time to the station, purpose, and AC are significant.

The signs of coefficients for waiting time, travel time, and travel cost are negative. This means that the BRT system in Jalalabad city, concerning modal shift, can be improved by reducing travel time, travel cost, and waiting time. Furthermore, the negative sign of purpose reveals that students are more interested in shifting to the BRT system than people who use a car for work or other purposes. Similar to share-taxis, the coefficient for AC also has a negative sign, indicating that buses with air conditioning will attract more passengers from cars.

BRT systems are increasingly adopted in numerous developing countries, serving as an urban transportation strategy to mitigate transport challenges. This research explores the factors influencing the modal shift from low-capacity vehicles (such as rickshaws, share-taxis, and private cars) to the BRT system in Jalalabad city. Echoing practical evidence from other locales, such as Beijing BRT Line 1 (Deng et al., 2012; ITDP, 2005), this research substantiates the argument that mindful consideration of BRT attributes can lure a considerable number of passengers from low-capacity vehicles.

The findings also indicate that present users of low-capacity vehicles exhibit noticeable sensitivity concerning various travel attributes, including travel time, cost, waiting period, walk duration to the station, availability of air conditioning, trip purpose, and gender.

The Ordered Logistic Regression (OLR) model was employed in this study to scrutinize Stated Preference (SP) data related to the BRT system in Jalalabad, Afghanistan, assessing modal choice behaviour concerning a shift from existing low-capacity vehicles to BRT.

**4.4 Summary**

This investigation has spotlighted several crucial factors related to the viability of the BRT system. It determined that the proposed BRT system holds the potential to draw a substantial user base from autos, share-taxis, and private cars.

The shift to the BRT system is notably influenced by specific attributes, such as travel duration, cost, waiting periods, walk distance to stations, availability of air conditioning, trip purpose, and gender. The research unveiled that the implementation of the BRT system will coax a significant portion of current low-capacity vehicle users to transition to the BRT system. Consequently, the introduction and operation of the BRT system are poised to notably impact city congestion levels.

The study concludes that a sizable segment of low-capacity vehicle users, including those using private cars, are discontented with the prevailing conditions in Jalalabad city and are predisposed to transition to the new alternative.

# CHAPTER 5

# ANALYSIS OF MODE CHOICE RELATIONSHIP WITH THE DENSITY IN KABUL CITY

## 5.1 General

The study  focuses on understanding how population density influences transportation choices in Kabul City. Land use characteristics might not have been included in the modeling of mode choice because the emphasis was possibly on understanding the direct impact of population density on transportation preferences, rather than the broader land use patterns. This specific aspect of urban planning how the arrangement and usage of land affects transportation choices could be complex and require a distinct methodological approach, possibly integrating detailed spatial analysis and urban form considerations beyond just population density.. Urban form is a fundamental element of urban planning which can lead the city toward sustainability or unsustainability. Commonly, urban form has a positive or a negative effect onresidents' quality Furthermore, Boontore A. (2014) assessed urban sprawl as a critical problem, such as low-capacity vehicle dependencies, increasing pollution and loss of land resources. There are several indicators to determine the level of sprawl, such as density, intensification, mixed-use, and road network. However, Cervero et al. (1996) stated that two factors (density and mixed-use) of urban form have a keen influence on travel behaviour. Hence, for the safe keeping of cities and successful operation of the transportation system, urbanplanners and engineers propose various solutions such as compact cities, intelligent cities, andgreen cities to keep the urban area sustainable for current and future inhabitants. However, Cervero et al. (1996) emphasized the significant influence of density and mixed use on travel behaviour. The primary objective of this section is to thoroughly investigate the relationship between urbansprawl and travel demand patterns. Building on the travel demand modelling elaborated in Chapter Three, this study seeks to quantify the level of compactness within different traffic zones of the city, exclusively using two pivotal indicators: density and mixed-use. Study area

### 5.1.1 A Study on Urbanization and Growth Dynamics in Kabul City

Kabul's history is believed to date back some 3,500 years. It successively fell under the control of Alexander the Great, Sassanian Persia, the Islamic Empire, the Timur Empire, the Mughal Empire, and others. Afghanistan came under the authority of the Durrani Dynasty in 1747, and

Kabul was designated its capital in 1775. After the struggle between Britain and Russia for dominance and subsequent British colonization, Afghanistan gained independence in 1919, with Kabul as its capital. By 1925, Kabul had a population of about 90,000. Today, the city's basic structure was laid out in the 1940s and 50s. During this time, residential development surged, and significant landmarks like Jadayi Maywand Street, Kabul University, hospitals, and bazaars were constructed. The city continued to expand after the 1950s, reaching 380,000 by 1962. The first master plan for the city was drafted between 1962-64 by Afghan and Russian experts, targeting a population of 800,000.

Urbanization in Kabul began in the old town of District 1, spanning 400ha in 1916. Between 1940 and 1962, urbanization accelerated, expanding the built-up area to $68km^2$. Notably, during the Mujahedin period from 1992 to 1999, the built-up area grew to 25,000ha. Over these 83 years, the Population experienced an average annual growth rate of 4.07%, attributed to both an influx of people and territorial expansion. The city's area grew by an impressive 62.5 times during this period.

In 2005, the Central Statistics Office (CSO) estimated Kabul City's Population to be 2,268,300, covering the older city area of 14 districts (Districts 1-16, excluding Districts 13 and 14). In January 2005, an agreement between the Ministry of Interior, the Kabul Province, and the Kabul Municipality resulted in expanding the Kabul Municipality's jurisdiction. Consequently, the Population surged to 2,721,000 across 22 districts. By 2008, the city's population was estimated at 4.22 million, marking an average annual increase of nearly 10% between 1999 and 2008. This significant rise was partly due to territorial expansion. Over the same period, the municipality's area expanded by 4.1 times, reaching 1,022.7 $km^2$. Informal settlements are essentially defined as developed areas. These settlements encompassed 76% of the total residential area in 2008. Concurrently, 74% of the city's population lived within these informal settlement areas that year (KMP 2011).

### 5.1.2 An Exploration of Population Trends in Kabul City

The Central Statistics Office (CSO), International Consultants & Technocrats (ICT) in connection with the Kabul Development Plan, and the JICA study team with the Kabul Metropolitan Area Development Master Plan have all estimated the Population of Kabul city. In 2008, the CSO estimated the city's Population to be 2.7 million across 16 districts. This estimate excludes the populations of six districts—Districts 14, 18, 19, 20, 21, and 22—later incorporated into the Kabul municipality. In contrast, the ICT's 2008 estimate stood at 4.5 million, with a projection of 8.0 million by 2023, as shown in Figure 5.1.

Meanwhile, the JICA study team estimated the 2008 population at 4.1 million. They projected it to reach 6.7 million by 2025 for the metropolitan area, which includes an expected 1.5 million in the newly developed city areas (KMP 2011).

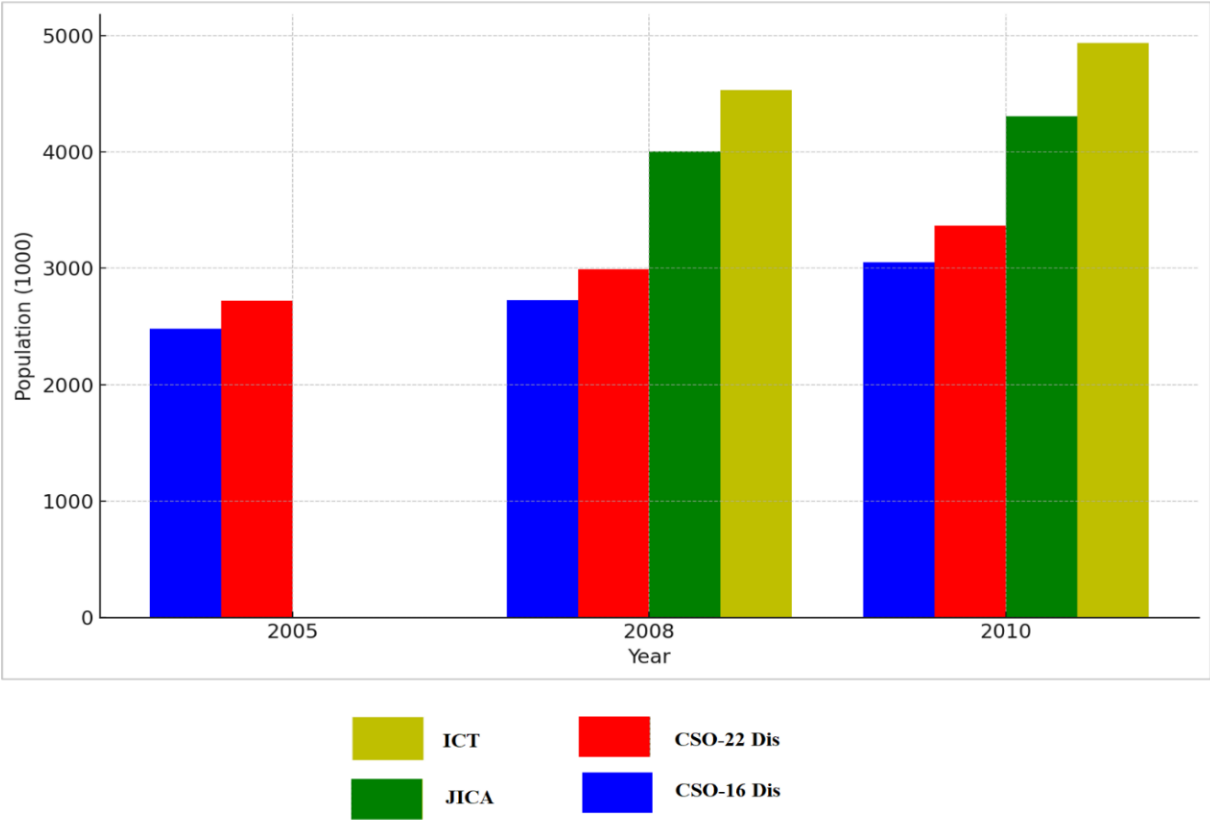



**Figure 5.1:** Population assessments for Kabul, as per research initiatives (KMP 2011)

Kabul is divided into 22 districts with unique population density characteristics. When examining the data, there are notable variances in the density metrics in the overall district areas and specifically within the residential zones. District 10 stands out with an impressive district density of 207 persons per hectare, making it the most densely populated district in Kabul. This is followed closely by District 11 and District 4, with densities of 165 and 174 persons per hectare, respectively. However, when focusing solely on residential areas, the landscape shifts slightly. District 11 has the highest residential area density, with 347 persons per hectare, suggesting that its residential zones are especially packed. District 3 and District 4 follow suit, each with a residential density exceeding 338 persons per hectare.

In contrast, some districts display remarkably low densities. District 19, for instance, has no overall district density and boasts a residential density of 356 persons per hectare. This indicates that while the district might be sparsely populated, its residential zones are intensely populated. On the other end of the spectrum, District 14, despite its expansive size, has a minimal district density of 12 persons per hectare and a residential density of 282 persons per hectare. Kabul's diverse density profile underscores the city's dynamic urban landscape, where some areas are bustling hubs of activity while others remain relatively calm. These variations can be attributed to numerous factors, including historical development patterns, economic opportunities, and urban planning strategies. Figure 5.2 shows the district density in Kabul city.

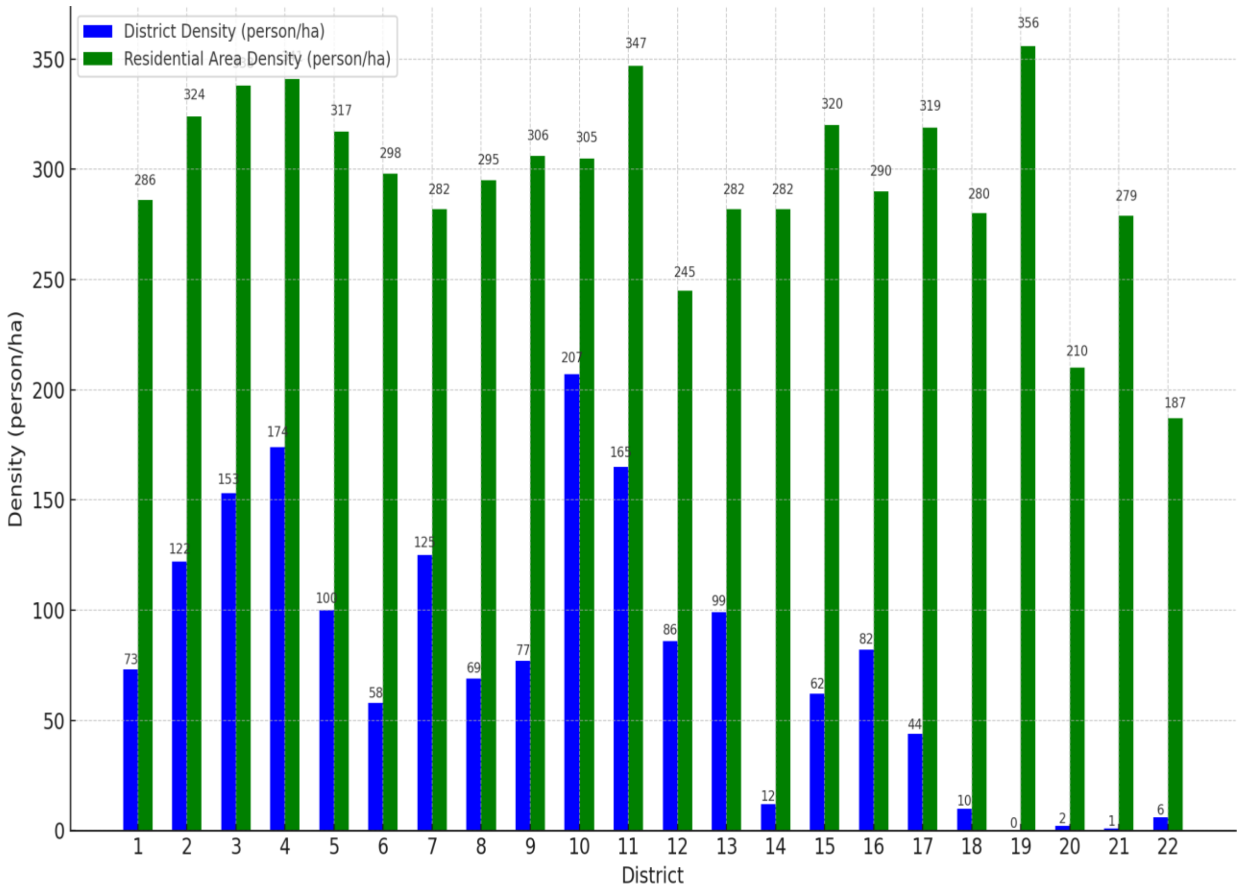
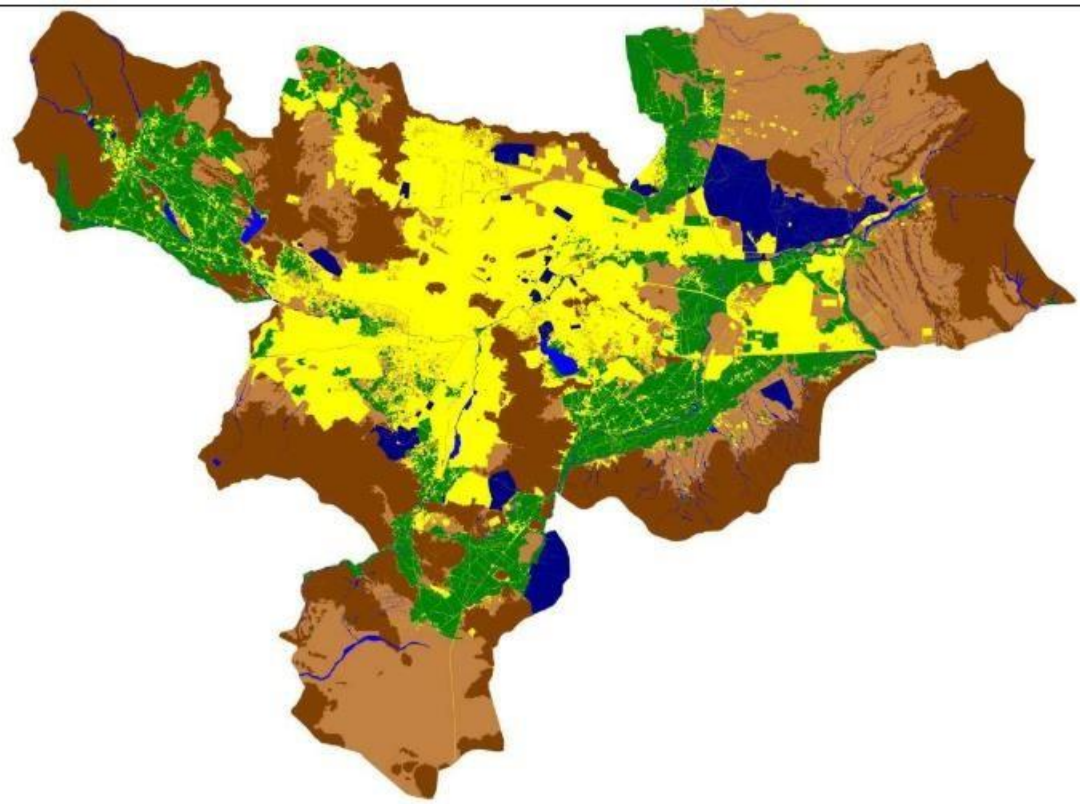



Figure 5.2 District Density in Kabul City (JICA, Report 9)

### 5.1.3 Evaluating Land Use Circumstances in Kabul City

Figure 5.3 depicts the land use in 2008, categorized broadly. As inferred from the figure, the gross population density was estimated at 177 persons/ha. This encompasses all the built-up areas, including residential, governmental, commercial, and industrial zones and lands designated for infrastructure such as airports, roads, and parks. It can be stated that land availability will not pose a significant constraint for Kabul City's future urban expansion, provided the entire municipal region is designated for urban development. However, specific crucial policies could influence the utilization of this land and further, special attention may need to be paid to infrastructural development.



| Category | Area (ha) | Share (%) | Density (Persons/ha) | Legend |
|---|---|---|---|---|
| Built-up area | 23,856 | 23.3 | 177 | |
| Building use | 18,342 | 17.9 | 230 | |
| Transport | 5,514 | 5.4 | | |
| Developable area | 46,543 | | | |
| Defense | 4,704 | 4.6 | | |
| Agriculture | 16,340 | 16.0 | | |
| Vacant | 25,500 | 24.9 | | |
| Hill | 30,133 | 29.5 | | |
| Water | 1,725 | 1.7 | | |
| Municipality Total | 102,258 | 100.0 | 41 | |

**Figure 5.3** land use in Kabul City in 2008 (KMP 2011)

### 5.2 Navigating the Process of Information Assembly

The data for this study were accurately sourced from the JICA Final Report (2009). This comprehensive report provides vital metrics, including population figures, employment statistics, and student counts. A notable aspect of the research methodology was incorporating Geographic Information System (GIS) tools. By utilizing the capabilities of GIS, the study could accurately describe and quantify areas designated for specific purposes within Kabul. GIS analysis pinpointed and measured areas such as parks, homes, businesses, and schools. In compactness calculations, the combined size of these areas was treated as one residential area. The city has 22 districts, each city has various Population, and each district consists of many

Gozars. In this study, to obtain appropriate and logical results, each Gozar considered a traffic zone. Figure 5.4 shows the 213 traffic zones in Kabul city.

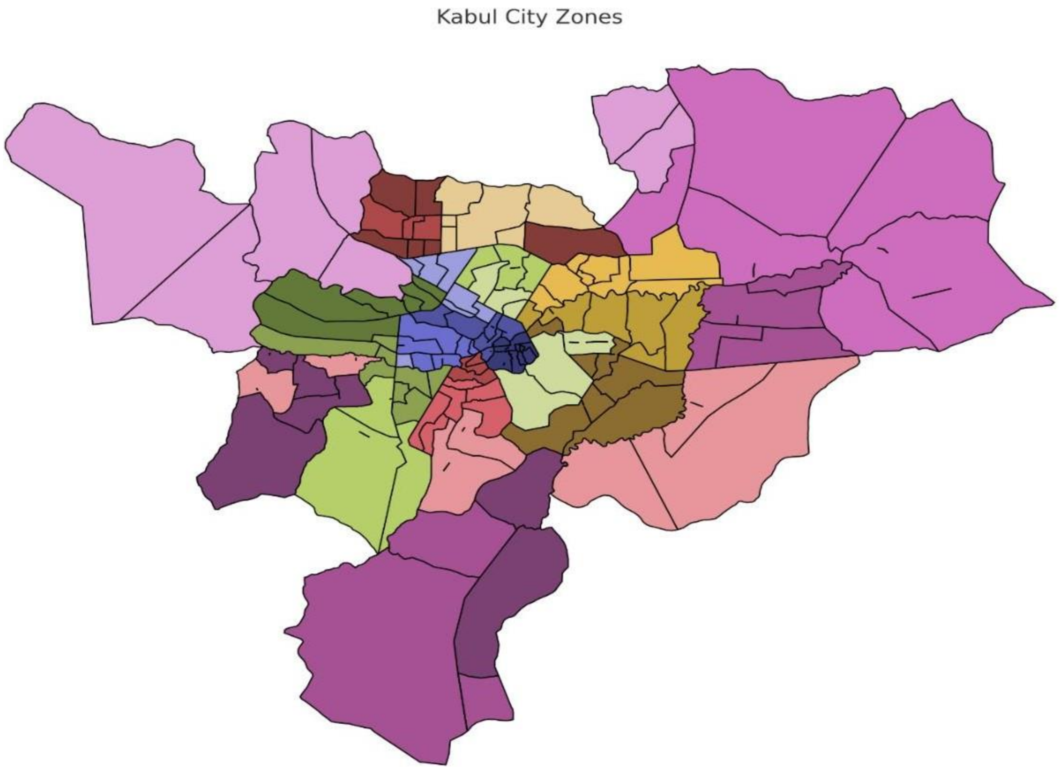



**Figure 5.4** 213 traffic zones in Kabul city

### 5.3 Examining the Relationship Between Mode Selection and Urban Density

Exploring the relationship between urban compactness and transportation choices within Kabul City begins with attention to the mode choice model. This model illuminates transportation preferences across Kabul's 213 traffic zones. A four-step prediction model found the number of passengers choosing different transportation methods, like public transport, walking, andprivate vehicles. Although the particulars of this model's development and its estimations are elaborated in Chapter Three, it is foundational for the current analysis. Adopting a compact urban framework, the research assesses two factors: land-use diversity and demographic density. Land-use diversity covers parks, homes, commercial centres, and schools. As noted earlier, these zones were grouped as residential areas during the compactness estimation. Demographic densities that cover the general Population, students and employment. In evaluating demographic density, densities for Population, employment, and student groups were quantified across district zones, built-up regions, and residential areas. However, a composite average of these factors was employed for the compactness assessment within each traffic zone. Before evaluating compactness, the ratios of density and mixed-use for each zone were determined. The compactness levels of the 213 traffic zones were then assessed using the metrics method (D. Stathakis et al. 2013 Burton.,2000).

For a detailed breakdown of the research methodology, Figure 5.5 offers a methodology flow chart. Furthermore, all estimations were conducted individually across Kabul's 22 districts and its 213 traffic zones for clarity.

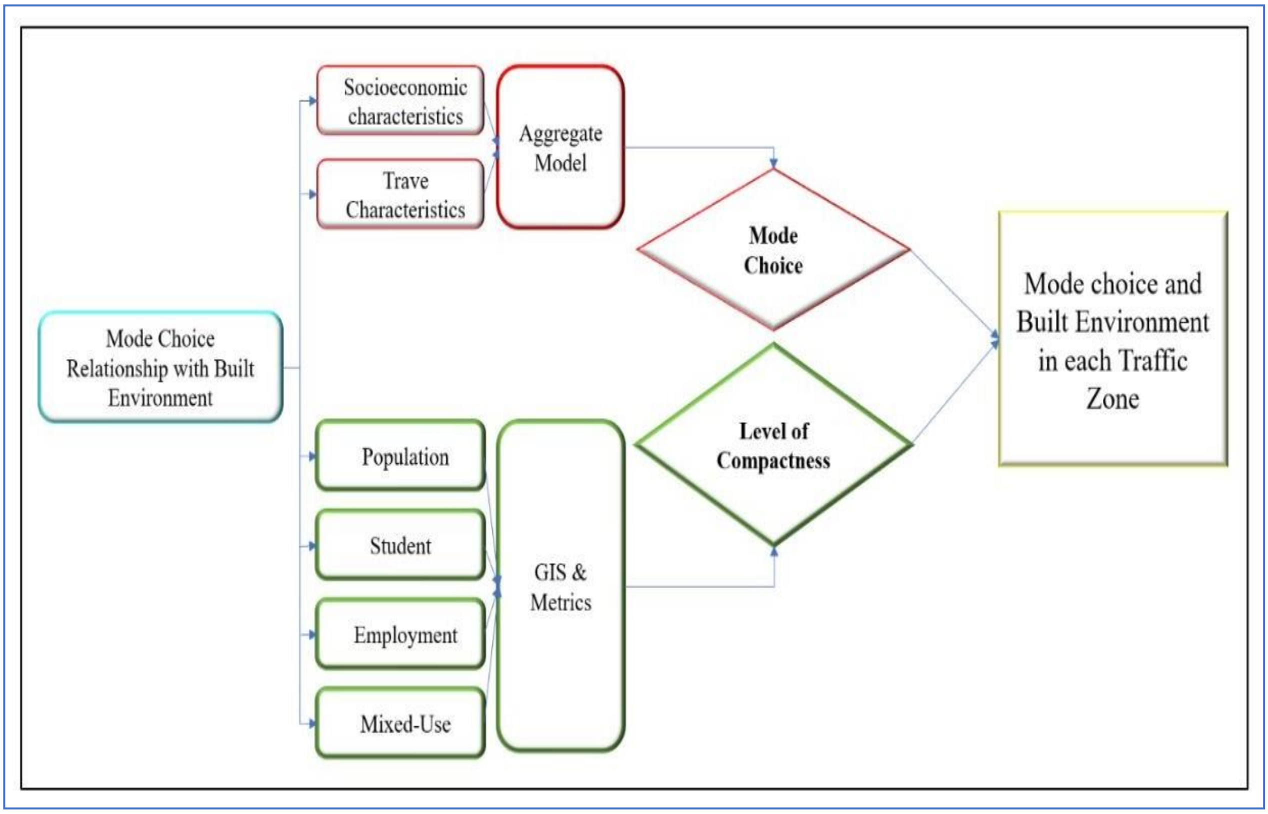



**Figure 5.5** Exploring the Link between Mode Choice and Density in Kabul City

### 5.3.1 Analyzing Mode Choice Models in Kabul City

The mode choice model is a pivotal tool in understanding transportation preferences, offering insights into three primary transportation modalities: public transport, walking, and private transport. This model employs a systematic approach, analysing various factors influencing an individual's decision to opt for one mode over another. These factors might include travel time, costs, accessibility, and convenience associated with each mode. The determinants of this model have been comprehensively detailed in Chapter Three. While the model clarifies the theoretical framework and influencing factors, the associated Figure 5.6 provides a visual representation, quantifying users for each transportation mode, thereby giving a clearer pictureof prevalent transportation trends.

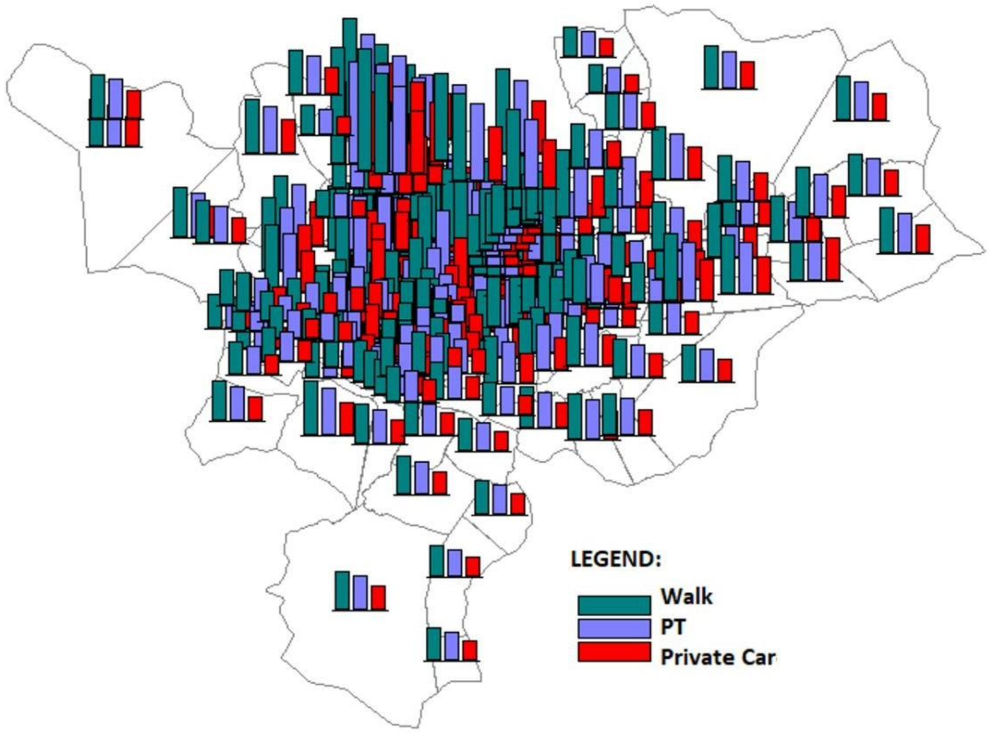



**Figure 5.6** Mode choice in Kabul city

**5.3.2 Estimation of Built Environment Parameters: A Focus on Density and Diversity**

The modern urban landscape includes structures, roads, parks, and other amenities. Understanding how spaces are organized and utilized is vital. Density and diversity are two key parameters that provide insights into this dynamic.

**Exploring into Density:**

Density in urban planning relates to the concentration of certain entities within a defined area. This study considers three fundamental parameters: population density, employment density and student density.

- ❖ Population Density: Defined as the number of people per unit area. It is an indicator of resource and service demand. This density is estimated in district, build-up, and residential areas to provide a comprehensive view of population spread and concentration.
- ❖ Employment Density: Represents the number of job locations per unit area. It highlights regions with high business activities. This density is estimated across district, built-up, and residential areas to capture the complete economic landscape.
- ❖ Student Density: Measures the number of students relative to educational institution areas, indicating educational infrastructure demand. The densities are analysed across district areas, built-up areas, and residential areas to understand the distribution of

educational institutions and their impact on urban planning. However, these factors were combined and averaged to determine compactness in each traffic zone, resulting in a single consolidated density value. Figure 5.7 shows the mentioned density across the district, build-up, and residential areas.

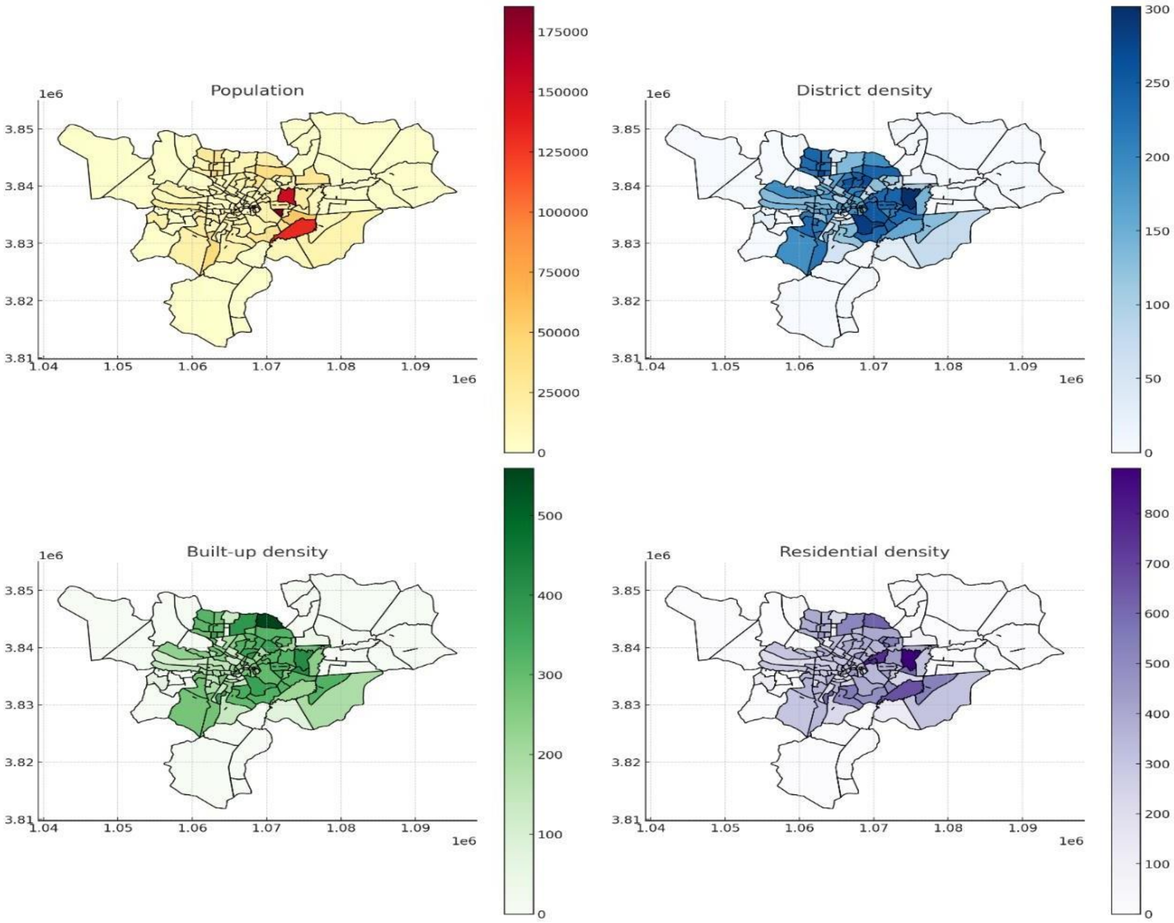



**Figure 5.7** Densities across district areas, built-up areas, and residential areas

**Exploring into Diversity (Mixed-Use):**

Urban land use diversity plays a crucial role in efficient city planning. This study estimates several mixed-use parameters for Kabul:

- ❖ Park Areas: Quantified by the amount of open green space per unit area, these regions are crucial for ecological balance and offer recreational outlets.
- ❖ Commercial Areas: Defined by the concentration of business establishments or commercial footprints per unit area, they provide insights into the economic activity density of the city.
- ❖ Residential Areas: Measured by the number of housing units or residential structures per unit area, this parameter indicates the housing density and can infer population distribution trends.

❖ School Areas: Represented educational institutions area is a direct metric of educational facility distribution and can indicate student density patterns. Utilizing GIS tools to map these parameters provides a detailed insight into Kabul's urban structure. Figure 5.8 illustrates the combined areas of parks, commercial zones, residential zones, and schools in Kabul city. The mentioned areas were summed up to determine compactness in each traffic zone, yielding a single value termed residential area.

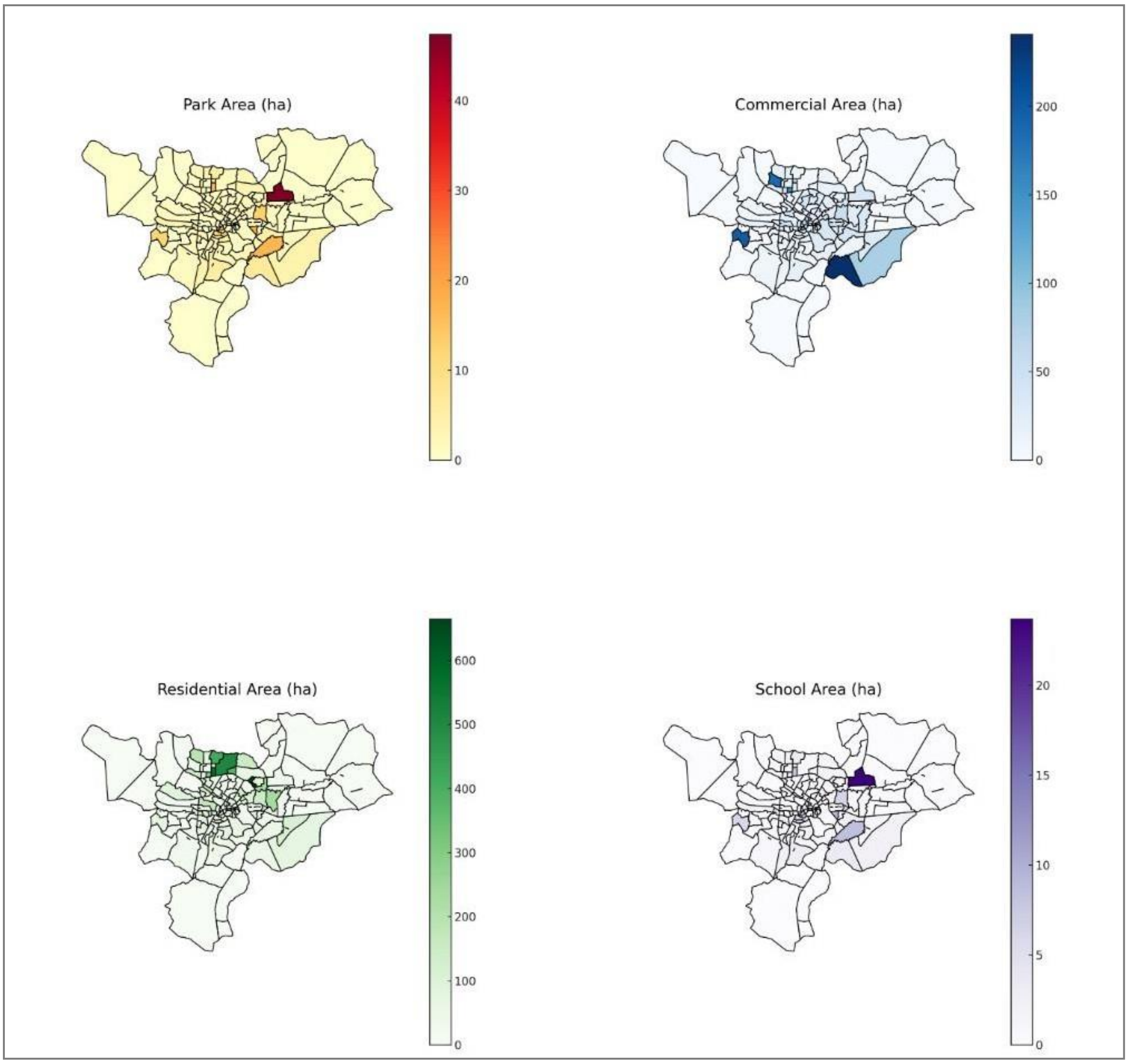



**Figure 5.8**: Highlighting mixed-use in Kabul city.

### 5.3.3 Measurement of Urban Compactness

Burton (2002) identified three indicators to measure urban sprawl and compactness in the literature: density, mixed-use, and intensification. In contrast, D. Stathakis and G. Tsilimigkas (2013) quantified the compactness of European cities using only density and mixed-use as metrics. Kenworthy et al. (1996) pointed out that high urban density can lead to shorter travel times, enhanced public transport, and increased walking and cycling. This research examines urban compactness or sprawl in two scenarios: within the 22 districts of Kabul city and across its 213 traffic zones.:

The average density (population, employment and student) indicator is subdivided into district density, residential density, and built-up density (Figure 5.9) and then estimates the supfacs2 (This is the ratio of residential area to non-residential area).

To ensure consistency and comparability, it is vital to standardize the values derived from the above calculations. Equation

$$S_{vi} = \frac{D_i - \mu}{SD} \tag{5.1}$$

Where:
*Svi* is the standardized value or z-score for traffic zone *i*.
*Di* is the Ave. density value for traffic zone *i*.
$\mu$ is the mean density of all traffic zones.
*SD* is the standard deviation of the density values across all traffic zones.

$$MU_i = \frac{Z_{area}}{B_{area} - R_{area}} \tag{5.2}$$

$MU_i$ is the mixed-use value for the traffic zone
$Z_{area}$ represents the total area of the zone
$B_{area}$ shows Built-up area within the zone
$R_{area}$ represents the residential area (commercial, school, park, residents area) within the zone

$$LC_i = \sum Ave.\ Sv_i + MU_i \tag{5.3}$$

$LC_i$ shows the level of compactness for zone i
For the districts, the subsequent steps are detailed in Table 5.1.

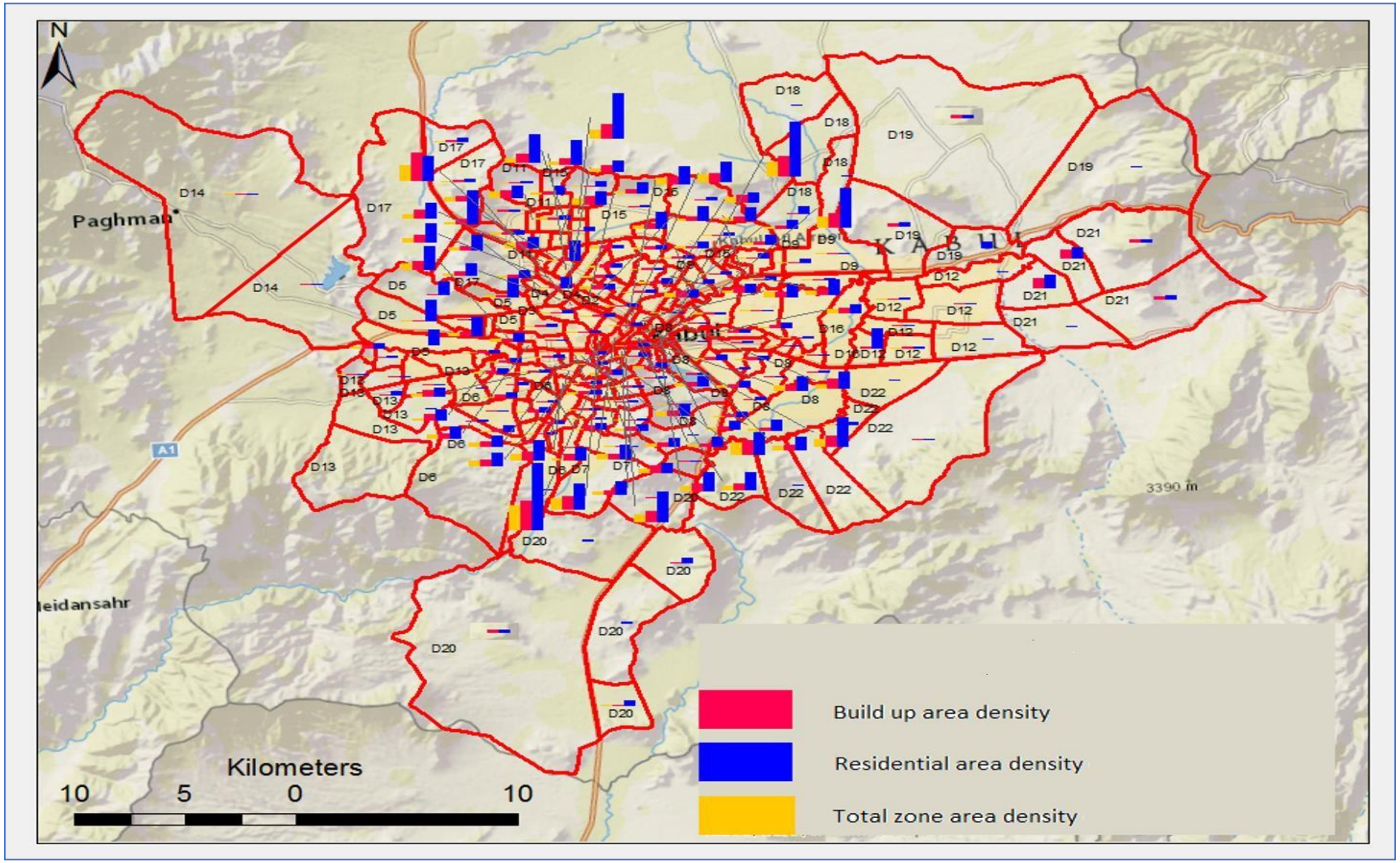



**Figure 5.9** Build-up, residential and district densities in each traffic zone

**Table 5.1** Evaluations of urban expansion or compactness degree in 22 Kabul city districts.

| Dis name | Population (Ave. population, employment, student) | Dis area (ha) | Build-up (ha) | Residential (ha) | $\alpha$ | $\beta$ | $\gamma$ | Mixed-use 2 | Dens | Level of Compactness |
|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | A | B | C | D | F | G |
| Jade Maiwand | 36727 | 483 | 332 | 124 | -0.206 | -1.017 | -0.299 | -0.57 | -0.51 | -0.54 |
| Karti Ariana | 127993 | 684 | 590 | 257 | 1.709 | 0.328 | -0.242 | -0.40 | 0.60 | 0.10 |
| Diburi | 81715 | 911 | 822 | 414 | 0.029 | -1.159 | -0.327 | -0.17 | -0.49 | -0.33 |
| Share Now | 189086 | 1172 | 1128 | 598 | 1.264 | -0.296 | -0.293 | -0.07 | 0.23 | 0.08 |
| Kote Sangi | 332403 | 2845 | 1532 | 894 | 0.497 | 0.329 | -0.278 | 0.19 | 0.18 | 0.19 |
| Allawoddin | 288912 | 4918 | 1671 | 957 | -0.504 | -0.229 | -0.297 | 0.13 | -0.34 | -0.11 |
| Guzargah | 452806 | 3334 | 2136 | 1,478 | 0.824 | 0.266 | -0.296 | 0.98 | 0.26 | 0.62 |
| Karte Naw | 576835 | 4825 | 1837 | 1,124 | 0.544 | 1.557 | -0.238 | 0.35 | 0.64 | 0.5 |
| Microrayan | 189919 | 2433 | 1803 | 616 | -0.171 | -1.084 | -0.296 | -0.64 | -0.52 | -0.58 |
| Bibi Mahroh | 246849 | 1303 | 1081 | 885 | 1.749 | 0.473 | -0.304 | 3.11 | 0.65 | 1.87 |
| Khair Khana | 273923 | 1742 | 1265 | 829 | 1.194 | 0.323 | -0.289 | 0.66 | 0.42 | 0.53 |
| Harzan Q | 424138 | 3490 | 2218 | 1,221 | 0.578 | 0.003 | -0.285 | 0.02 | 0.11 | 0.06 |
| Dashte Barchi | 435384 | 4719 | 2698 | 1,660 | 0.073 | -0.375 | -0.308 | 0.37 | -0.20 | 0.08 |
| Qargha | 210977 | 11902 | 951 | 524 | -1.212 | 0.390 | -0.269 | 0.02 | -0.36 | -0.17 |
| Qasaba | 207553 | 3253 | 2000 | 626 | -0.417 | -1.104 | -0.289 | -0.70 | -0.60 | -0.65 |
| Microrayan K | 325245 | 2507 | 941 | 713 | 0.720 | 1.957 | -0.254 | 1.81 | 0.81 | 1.31 |
| Kotal | 327575 | 5602 | 1543 | 780 | -0.509 | 0.270 | -0.264 | -0.17 | -0.17 | -0.17 |
| Paimonar | 52722 | 3388 | 584 | 121 | -1.249 | -1.275 | -0.260 | -0.88 | -0.93 | -0.90 |
| Dehsabz | 184369 | 14143 | 1586 | 11 | -1.292 | -0.946 | 4.308 | -1.12 | 0.69 | -0.22 |
| Reshkhor | 174334 | 14294 | 1319 | 152 | -1.307 | -0.745 | -0.061 | -1.00 | -0.70 | -0.85 |
| Pole Charkhi | 107260 | 6395 | 281 | 22 | -1.228 | 2.414 | 0.983 | -1.05 | 0.72 | -0.16 |
| Kamari | 221462 | 7925 | 1243 | 258 | -1.035 | -0.162 | -0.142 | -0.88 | -0.45 | -0.66 |

For more explanation, the level of compactness only for one district (Jade Maiwand) is estimated as follows:

Name of District: Jade Maiowand.

Population (a): 36727 Dis area (b):483 ha Build-up area (c): 332 ha Residential area: 124 ha

$\alpha\ (A) = [(a \div b) - mean] \div SD$ = {[ (36727 ÷ 483) − 88] ÷ 58} = −0.206

$\beta\ (B) = [(a \div c) - mean] \div SD$ = {[ (36727 ÷ 332) − 191] ÷ 79} = −1.017

$\gamma\ (C) = [(a \div d) - mean] \div SD$ = {[ (36727 ÷ 124) − 1364] ÷ 3570} = −0.299

$Mixed - use\ (D) = \{[(d \div (c - d)\ ] - mean\} \div SD$ = {[124 ÷ (332 − 124) ] − 1.2} ÷ 1.07 = −0.57

$F = [(A + B + C)/3]$ = [(−0.206) + (−1.017) + (−0.299)/3] = −0.51

$G = [(D + F)/2]$ = [(−0.57) + (−0.51)] = −0.54

If α, β, γ are variables representing densities in district, built-up, and residential areas respectively.

With an intricate interplay between spatial compactness and transportation mode choice elucidated in Table 5.3, the study dives deeper into evaluating the intrinsic patterns and divergences across the 22 districts and 213 traffic zones. The emphasis is placed on discerning how urban form and density—reflected through various measures of compactness—influence and possibly predicate travel behavior amongst the populace. The analysis ventures beyond mere observation, embedding itself in a comprehensive examination that seeks to untangle the myriad of factors that conspire to shape mobility patterns. The subsequent exploration strives to encompass the multifaceted layers of urban and transport planning, including considerations of accessibility, cost, and demographic inclinations, all while navigating through the intricate urban tapestry of Kabul’s distinct districts and traffic zones. It provides a robust framework that may inform future urban planning and policy-making, underscoring the potential for strategic interventions that align with both the micro and macro-level mobility characteristics and preferences of the inhabitants. Consequently, the interwoven data from Tables 5.2 and 5.3 serve not only as a snapshot of the current state but also as a directional compass, pointing towards areas that may benefit from targeted transportation and urban development strategies.

**Table 5.2** Trip production via diverse transportation methods in surveyed regions

| No of District | Name of District | Walk | Walk (%) | PT | PT (%) | Car | Car (%) | All Mode |
|---|---|---|---|---|---|---|---|---|
| 1 | Jade Maiwand | 5022 | | 26161 | 52 | 19041 | 38 | 50224 |
| 2 | Karti Ariana | 6235 | 11 | 31028 | 52 | 21959 | 37 | 59222 |
| 3 | Diburi | 10022 | 11 | 48352 | 53 | 33348 | 36 | 91722 |
| 4 | Share Now | 25643 | 11 | 122131 | 53 | 80667 | 35 | 228441 |
| 5 | Kote Sangi | 24979 | 12 | 109528 | 54 | 66698 | 33 | 201205 |
| 6 | Allawoddin | 18047 | 12 | 82194 | 54 | 51591 | 34 | 151832 |
| 7 | Guzargah | 30994 | 15 | 119746 | 56 | 62437 | 29 | 213177 |
| 8 | Karte Naw | 33229 | 14 | 128848 | 55 | 71523 | 31 | 233600 |
| 9 | Microrayan | 20198 | 9 | 102490 | 48 | 90199 | 42 | 212887 |
| 10 | Bibi Mahroh | 49622 | 18 | 159084 | 58 | 67660 | 24 | 276366 |
| 11 | Khair Khana | 21265 | 15 | 78925 | 56 | 41322 | 29 | 141512 |
| 12 | Harzan Q | 15985 | 12 | 71533 | 54 | 45748 | 34 | 133266 |
| 13 | Dashte Barchi | 28097 | 13 | 117363 | 55 | 66089 | 31 | 211549 |
| 14 | Qargha | 12588 | 14 | 49591 | 53 | 30986 | 33 | 93165 |
| 15 | Qasaba | 26000 | 9 | 138135 | 48 | 124529 | 43 | 288664 |
| 16 | Microrayan K | 18752 | 17 | 63902 | 57 | 29990 | 27 | 112644 |
| 17 | Kotal | 20536 | 11 | 103038 | 53 | 71621 | 37 | 195195 |
| 18 | Paimonar | 23790 | 8 | 145779 | 47 | 138773 | 45 | 308342 |
| 19 | Dehsabz | 35491 | 13 | 137739 | 52 | 91725 | 35 | 264955 |
| 20 | Reshkhor | 9101 | 9 | 47995 | 47 | 44855 | 44 | 101951 |
| 21` | Pole Charkhi | 7901 | 12 | 33816 | 52 | 23820 | 36 | 65537 |
| 22 | Kamari | 5687 | 10 | 27427 | 48 | 24397 | 42 | 57511 |
| Total | | 449184 | | 1944804 | | 1298978 | | 3,692,969 |

**Table 5.3** Travel demand for all modalities in both dense and expanded regions of Kabul city

| District No | District Name | Level of Sprawl | Walk Users (%) | PT Users (%) | Car (%) |
|---|---|---|---|---|---|
| 10 | Bibi Mahroh | 1.87 | 18 | 58 | 24 |
| 16 | Microrayan Kohna | 1.31 | 17 | 57 | 27 |
| 8 | Karte Naw | 0.5 | 14 | 55 | 31 |
| 11 | Khair Khana | 0.53 | 15 | 56 | 29 |
| 7 | Guzargah | 0.62 | 15 | 56 | 29 |
| 2 | Karti Ariana | 0.10 | 11 | 52 | 37 |
| 5 | Kote Sangi | 0.19 | 12 | 54 | 33 |
| 4 | Shari Now | 0.08 | 11 | 53 | 35 |
| 12 | Harzan Q | 0.06 | 12 | 54 | 34 |
| 13 | Dashte Barchi | 0.08 | 13 | 55 | 31 |
| 21 | Pole Charkhi | -0.16 | 12 | 52 | 36 |
| 17 | Kotal | -0.17 | 11 | 53 | 37 |
| 6 | Allawoddin | -0.11 | 12 | 54 | 34 |
| 14 | Qargha | -0.17 | 14 | 53 | 33 |
| 3 | Diburi | -0.33 | 11 | 53 | 36 |
| 1 | Jade Maiwand | -0.54 | 10 | 52 | 38 |
| 19 | Dehsabz | -0.22 | 13 | 52 | 35 |
| 9 | Microrayan | -0.58 | 9 | 48 | 42 |
| 22 | Kamari | -0.66 | 10 | 48 | 42 |
| 15 | Qasaba | -0.65 | 9 | 48 | 43 |
| 20 | Reshkhor | -0.85 | 9 | 47 | 44 |
| 18 | Paimonar | -0.9 | 8 | 47 | 45 |

The level of sprawl in Table 5.3 on page is defined through the compactness assessment of each traffic zone or district in Kabul. It was computed using the following elements: Density Measures: Considers population, employment, and student density within zone, residential, and built-up areas. Mixed-Use Value (MUi): Assesses the diversity of land use within each zone, calculated as the ratio of the total area of the zone to the difference between the built-up area and the residential area. Standardized Density Value (Svi): Represents the z-score for each traffic zone, calculated by normalizing the density value of each zone against the mean and standard deviation of density values across all traffic zones. Level of Compactness (LCi): Sum of the average standardized density value (Svi) and mixed-use value (MUi) for each zone, indicating the compactness or sprawl level. The level of sprawl is thus an inferred measure based on these calculations, with a lower level of compactness indicating higher sprawl, and vice versa.

## 5.4 Summary

The results illustrate distinct values concerning user percentages for different modes. Table 5.1 differentiates areas based on their levels of compactness, distinguishing between high levels of compactness, low levels of compactness, and sprawling districts. The findings indicate that districts 1, 2, 9, 13, 14, 15, 17, 18, 19, 20, and 22 are sprawl areas, while districts 2, 4, 5, 12, and 21 exhibit low compactness. In contrast, districts 10, 16, 8, 11, and 7 are characterized by a comparatively high level of compactness.

This section evaluates the impact of urban sprawl and urban compactness on travel demand by analysing the data from Tables 5.1 and 5.2. The results, summarized in Table 5.3, show that in sprawling areas such as Paimonar, Reshkhor, Qasaba, Kamari, Microrayan, Dehsabz, Jade Maiwand, Diburi, Qargha, Allawoddin, Kotal, and Dashte Barchi, a smaller percentage of people are inclined towards walking and using public transportation compared to those in compact areas like Bibi Mahroh, Microrayan Kohna, Karte Naw, Khair Khana, and Guzargah. Conversely, residents of highly sprawling districts prefer private transportation more than those in other observed districts.

Karti Arian, Qalai-i-Wazir, Shar Naw, Harzan Q, and Pole Charkhi are classified as having minor sprawl. In these districts, the percentage of people using public transportation and walking is higher than in sprawling areas but lower than in compact areas. Results indicate that Bibi Maharoh, Microrayan Kohna, Chahl Sotun, and Khair Khana are the most compact districts in Kabul city. Consequently, these districts see more users opting for public transport and walking than other districts. However, a smaller percentage of travellers in these compact areas prefer private transportation than their counterparts in non-compact districts. In conclusion, the research reveals that residents of sprawling areas tend to favour low-capacity vehicles and generally exhibit less interest in walking or utilizing public transport systems.

# CHAPTER 6
# SUMMARY AND CONCLUSION

## 6.1 General

The following chapter summarizes the findings of the study regarding Bus Rapid Transit system possibilities concerning corridor selection based on high travel demand, modal shift from existing low-capacity vehicles to purpose BRT system in two major cities (Kabul and Jalalabad) and finally, the relationship between Land-use and mode choice. Furthermore, it includes limitations of the study and scope for future work.

## 6.2 Summary

The main objective of this study is to develop models for describing BRT system possibilities and the relationship between land use and mode choice. Kabul City and Jalalabad City were considered as study areas. The cities are most significant metropolitan cities in Afghanistan regarding traffic and urban form.

A preliminary survey revealed the lack of sufficient and efficient high-capacity public transport (MRT) systems in both cities and segregation among land-use and transportation systems in Kabul city create problems such as congestion, high accident levels and air pollution. To evaluate efficient MRT system possibilities, travel demand, modal shift and the relationship between land-use and travel behaviours are the key concepts that should be analysed. The mentioned concepts can affect various variables, such as household characteristics, travel features and built environment characteristics.

In order to select the BRT corridor, travel demand has been modelled and forecasted in the first phase. Traditional four-stem models (trip generation, trip distribution, mode choice and trip assignment) were suggested. In this part of the study, the research has been carried out to understand the impact of various variables on travel demand. Population, car ownership, employment, density, travel distance and travel time were considered significant variables. Modal shift is another fundamental concern regarding introducing a competent BRT system. Hence, it was required to develop the modal shift model to understand the influential variables. Existing modes (auto, share-taxi and car) and purposed BRT mode were observed as dependent variables and household characteristics (gender, car ownership, driving license, age and trip purpose).

BRT attributes (travel cost, travel time, waiting time, walking time, air-conditioning, station type, distance between stations and corridor type) were considered independent variables using the Ordinal Logistic Regression (OLR) model. The model results indicate that travel time, travel cost, waiting time and walking time are the most significant variables.

The third part of this study is dedicated to the relationship between land-use attributes and modal choice. The land-use attributes were estimated, and each traffic zone's level of compactness ratio was identified. The results revealed that people are more interested in walking and public transport in the area with a higher ratio. While in the traffic zones with lower ratio people are attracted by car.

### 6.3 Conclusion

1. The urban transport analysis in Kabul indicates that car ownership is significant predictors of trip production, These insights are fundamental in planning of of BRT system.
2. Travel distance is a significant factor in Kabul's transportation analysis, directly influencing trip distribution and playing a pivotal role in strategizing the forthcoming implementation of the BRT system within the city.
3. Acknowledging travel time's pivotal role in shaping transportation mode choices in Kabul, this crucial insight will be instrumental in strategizing the incorporation and optimization of the Bus Rapid Transit (BRT) system within the city's existing transportation framework.
4. Travel cost, time, and waiting periods are pivotal factors affecting mode choice across all vehicle users (rickshaw, share-taxi, and private car), with a notable emphasis on reducing these parameters to enhance BRT adoption.
5. The gender variable is significant among share-taxi users, with women potentially perceiving BRT as a safer option, while access to air conditioning in BRT vehicles could further attract users amidst Jalalabad's heat, particularly among private car and share-taxi commuters.
6. While the OLR models for rickshaw and share-taxi users exhibit solid reliability with $\rho 2$ values of 0.41 and 0.34 respectively, the model for private car users presents a weaker fit ($\rho 2$=0.23), indicating a potential need for further refinement to accurately predict modal shift in this segment.

7. In Kabul City's urban density was directly correlated with mode choices, seeing denser districts exhibit a higher propensity for walking and public transportation use.
8. Sprawl areas demonstrated a clear preference for private transportation, influenced by their widespread layouts and potentially limited access to public transit.
9. Land-use factor like population significantly predicts a rise in trip production in Kabul city.
10. Employment is a notable influencer in both trip production and attraction, where each unit increase expects to elevate trips by coefficients of 0.134 and 0.776 respectively, emphasizing its importance in transportation modeling.

## 6.3 Limitations

- Data Limitations: The travel demand modeling might be restricted by the available data quality and comprehensiveness for both Kabul and Jalalabad cities.
- Corridor Focus: The selection of BRT corridors, while informed, may not encompass all possible alternative routes or future urban development pathways.
- User Willingness: Estimations of modal shift willingness towards the BRT system might not fully represent actual shifts post-implementation due to varying real-world factors.
- Survey Constraints: If Stated Preference (SP) survey methods were utilized, responses might not always align with actual future traveler behaviors in real-world scenarios

## 7.0 Scope for the Future Work

- Diverse urban contexts may present varying levels of effectiveness and applicability for the BRT system.
- It could be that infrastructure design and accessibility significantly influence modal shifts and travel behaviour.
- Emerging transportation technologies like ride-sharing and electric vehicles might significantly affect modal choices and sustainability.
- The BRT system and alternative transportation modes could have substantial social equity implications, impacting fair access and benefits across different socio-economic groups

# Appendix

Table A1: Travel mode model result in 213 zones in Kabul city

| Des | Zone NO | All Mode | Non - Motorized | Motorized | PT | Car | Bus | Para Transit | Minibus | Microbus |
|---|---|---|---|---|---|---|---|---|---|---|
| D1 | 1 | 14024 | 1402 | 12622 | 7292 | 5329 | 452 | 6840 | 4069 | 2771 |
| | 2 | 16717 | 1672 | 15045 | 8693 | 6352 | 539 | 8154 | 4851 | 3303 |
| | 3 | 17145 | 1715 | 15431 | 8915 | 6515 | 553 | 8363 | 4975 | 3388 |
| | 4 | 14817 | 1482 | 13335 | 7705 | 5630 | 478 | 7227 | 4299 | 2928 |
| | 5 | 15699 | 1570 | 14129 | 8163 | 5966 | 506 | 7657 | 4555 | 3102 |
| | 6 | 14912 | 1491 | 13421 | 7754 | 5667 | 481 | 7273 | 4327 | 2947 |
| | 7 | 16308 | 1631 | 14677 | 8480 | 6197 | 526 | 7954 | 4732 | 3222 |
| | 8 | 14711 | 1471 | 13240 | 7650 | 5590 | 474 | 7175 | 4269 | 2907 |
| | 9 | 15377 | 1538 | 13839 | 7996 | 5843 | 496 | 7500 | 4462 | 3038 |
| | 10 | 16463 | 1646 | 14817 | 8561 | 6256 | 531 | 8030 | 4777 | 3253 |
| | 11 | 15796 | 1580 | 14216 | 8214 | 6002 | 509 | 7705 | 4583 | 3121 |
| | 12 | 14797 | 1480 | 13317 | 7694 | 5623 | 477 | 7217 | 4293 | 2924 |
| | 13 | 14639 | 1464 | 13175 | 7612 | 5563 | 472 | 7140 | 4248 | 2893 |
| | 14 | 16304 | 1630 | 14674 | 8478 | 6196 | 526 | 7952 | 4731 | 3222 |
| D2 | 15 | 26058 | 2866 | 23192 | 13550 | 9641 | 854 | 12696 | 7683 | 5014 |
| | 16 | 24957 | 2745 | 22212 | 12978 | 9234 | 818 | 12160 | 7358 | 4802 |
| | 17 | 22415 | 2466 | 19949 | 11656 | 8294 | 734 | 10921 | 6609 | 4313 |
| | 18 | 21215 | 2334 | 18881 | 11032 | 7850 | 695 | 10337 | 6255 | 4082 |
| | 19 | 24243 | 2667 | 21576 | 12606 | 8970 | 794 | 11812 | 7148 | 4664 |
| | 20 | 10187 | 1121 | 9066 | 5297 | 3769 | 334 | 4964 | 3004 | 1960 |
| | 21 | 18208 | 2003 | 16205 | 9468 | 6737 | 596 | 8872 | 5368 | 3503 |
| | 22 | 19959 | 2195 | 17764 | 10379 | 7385 | 654 | 9725 | 5885 | 3840 |
| | 23 | 20204 | 2222 | 17982 | 10506 | 7475 | 662 | 9844 | 5957 | 3887 |
| | 24 | 16023 | 1763 | 14260 | 8332 | 5929 | 525 | 7807 | 4724 | 3083 |
| | 25 | 21789 | 2397 | 19392 | 11330 | 8062 | 714 | 10616 | 6424 | 4192 |
| D3 | 26 | 15469 | 1702 | 13767 | 8199 | 5569 | 525 | 7674 | 4722 | 2951 |
| | 27 | 26625 | 2929 | 23696 | 14111 | 9585 | 903 | 13208 | 8128 | 5080 |
| | 28 | 20119 | 2213 | 17906 | 10663 | 7243 | 682 | 9981 | 6142 | 3839 |
| | 29 | 25864 | 2845 | 23019 | 13708 | 9311 | 877 | 12831 | 7896 | 4935 |
| | 30 | 22288 | 2452 | 19836 | 11813 | 8024 | 756 | 11057 | 6804 | 4253 |
| | 31 | 17707 | 1948 | 15759 | 9385 | 6375 | 601 | 8784 | 5406 | 3378 |
| | 32 | 20276 | 2230 | 18046 | 10746 | 7299 | 688 | 10059 | 6190 | 3869 |
| | 33 | 20686 | 2275 | 18411 | 10964 | 7447 | 702 | 10262 | 6315 | 3947 |
| | 34 | 20662 | 2273 | 18389 | 10951 | 7438 | 701 | 10250 | 6308 | 3942 |
| | 35 | 16629 | 1829 | 14800 | 8813 | 5986 | 564 | 8249 | 5077 | 3173 |
| | 36 | 19986 | 2198 | 17788 | 10593 | 7195 | 678 | 9915 | 6101 | 3813 |
| | 37 | 17883 | 1967 | 15916 | 9478 | 6438 | 607 | 8871 | 5459 | 3412 |
| D4 | 38 | 18421 | 2026 | 16210 | 9763 | 6447 | 635 | 9129 | 5711 | 3417 |
| | 39 | 20437 | 2248 | 17985 | 10832 | 7153 | 704 | 10128 | 6336 | 3791 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40 | 17032 | 1874 | 14988 | 9027 | 5961 | 587 | 8440 | 5281 | 3159 |
| | 41 | 23906 | 2630 | 21037 | 12670 | 8367 | 824 | 11847 | 7412 | 4435 |
| | 42 | 29885 | 3287 | 26299 | 15839 | 10460 | 1030 | 14810 | 9266 | 5544 |
| | 43 | 28791 | 3167 | 25336 | 15259 | 10077 | 992 | 14267 | 8927 | 5341 |
| | 44 | 22440 | 2468 | 19747 | 11893 | 7854 | 773 | 11120 | 6958 | 4163 |
| | 45 | 22936 | 2523 | 20184 | 12156 | 8028 | 790 | 11366 | 7111 | 4255 |
| | 46 | 29164 | 3208 | 25664 | 15457 | 10207 | 1005 | 14452 | 9042 | 5410 |
| | 47 | 25887 | 2848 | 22781 | 13720 | 9060 | 892 | 12828 | 8026 | 4802 |
| | 48 | 19436 | 2138 | 17104 | 10301 | 6803 | 670 | 9632 | 6026 | 3605 |
| | 49 | 27653 | 3042 | 24335 | 14656 | 9679 | 953 | 13703 | 8574 | 5130 |
| | 50 | 23340 | 2567 | 20539 | 12370 | 8169 | 804 | 11566 | 7237 | 4330 |
| | 51 | 16968 | 1866 | 14932 | 8993 | 5939 | 585 | 8408 | 5261 | 3148 |
| | 52 | 22891 | 2518 | 20144 | 12132 | 8012 | 789 | 11344 | 7097 | 4246 |
| D5 | 53 | 30779 | 3693 | 26778 | 16621 | 10157 | 1114 | 15507 | 10022 | 5485 |
| | 54 | 32647 | 3918 | 28403 | 17629 | 10774 | 1181 | 16448 | 10631 | 5818 |
| | 55 | 39224 | 4707 | 34125 | 21181 | 12944 | 1419 | 19762 | 12772 | 6990 |
| | 56 | 45373 | 5445 | 39475 | 24501 | 14973 | 1642 | 22860 | 14774 | 8085 |
| | 57 | 26846 | 3222 | 23356 | 14497 | 8859 | 971 | 13526 | 8742 | 4784 |
| | 58 | 28739 | 3449 | 25003 | 15519 | 9484 | 1040 | 14479 | 9358 | 5121 |
| | 59 | 33547 | 4026 | 29186 | 18115 | 11071 | 1214 | 16902 | 10924 | 5978 |
| D6 | 60 | 17528 | 2103 | 15425 | 9465 | 5960 | 625 | 8840 | 5622 | 3218 |
| | 61 | 12051 | 1446 | 10605 | 6508 | 4097 | 429 | 6078 | 3865 | 2213 |
| | 62 | 13652 | 1638 | 12014 | 7372 | 4642 | 487 | 6886 | 4379 | 2507 |
| | 63 | 13455 | 1615 | 11840 | 7266 | 4575 | 480 | 6786 | 4316 | 2470 |
| | 64 | 16291 | 1955 | 14336 | 8797 | 5539 | 581 | 8217 | 5226 | 2991 |
| | 65 | 13797 | 1656 | 12141 | 7450 | 4691 | 492 | 6959 | 4426 | 2533 |
| | 66 | 12736 | 1528 | 11208 | 6877 | 4330 | 454 | 6424 | 4085 | 2338 |
| | 67 | 18202 | 2184 | 16018 | 9829 | 6189 | 649 | 9180 | 5838 | 3342 |
| | 68 | 14728 | 1767 | 12961 | 7953 | 5008 | 525 | 7428 | 4724 | 2704 |
| | 69 | 14172 | 1701 | 12471 | 7653 | 4818 | 505 | 7148 | 4546 | 2602 |
| | 70 | 12633 | 1516 | 11117 | 6822 | 4295 | 450 | 6372 | 4052 | 2319 |
| | 71 | 13611 | 1633 | 11978 | 7350 | 4628 | 485 | 6865 | 4366 | 2499 |
| | 72 | 15814 | 1898 | 13916 | 8540 | 5377 | 564 | 7976 | 5072 | 2903 |
| | 73 | 14512 | 1741 | 12771 | 7836 | 4934 | 517 | 7319 | 4655 | 2664 |
| | 74 | 18981 | 2278 | 16703 | 10250 | 6454 | 676 | 9573 | 6088 | 3485 |
| D10 | 75 | 24687 | 4444 | 20243 | 14318 | 5925 | 1088 | 13230 | 9794 | 3436 |
| | 76 | 33613 | 6050 | 27563 | 19496 | 8067 | 1482 | 18014 | 13335 | 4679 |
| | 77 | 30524 | 5494 | 25030 | 17704 | 7326 | 1345 | 16358 | 12109 | 4249 |
| | 78 | 30227 | 5441 | 24786 | 17532 | 7254 | 1332 | 16199 | 11992 | 4208 |
| | 79 | 27975 | 5036 | 22940 | 16226 | 6714 | 1233 | 14992 | 11098 | 3894 |
| | 80 | 36596 | 6587 | 30009 | 21226 | 8783 | 1613 | 19613 | 14518 | 5094 |
| | 81 | 27131 | 4884 | 22247 | 15736 | 6511 | 1196 | 14540 | 10763 | 3777 |
| | 82 | 26046 | 4688 | 21358 | 15107 | 6251 | 1148 | 13959 | 10333 | 3626 |
| | 83 | 29661 | 5339 | 24322 | 17203 | 7119 | 1307 | 15896 | 11767 | 4129 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 84 | 32246 | 5804 | 26442 | 18703 | 7739 | 1421 | 17281 | 12793 | 4489 |
| | 85 | 26896 | 4841 | 22055 | 15600 | 6455 | 1186 | 14414 | 10670 | 3744 |
| D8 | 86 | 11311 | 1584 | 9727 | 6221 | 3506 | 429 | 5792 | 3863 | 1929 |
| | 87 | 14969 | 2096 | 12873 | 8233 | 4640 | 568 | 7665 | 5113 | 2552 |
| | 88 | 18311 | 2564 | 15747 | 10071 | 5676 | 695 | 9376 | 6254 | 3122 |
| | 89 | 17591 | 2463 | 15128 | 9675 | 5453 | 668 | 9007 | 6008 | 2999 |
| | 90 | 18140 | 2540 | 15600 | 9977 | 5623 | 688 | 9289 | 6196 | 3093 |
| | 91 | 11816 | 1654 | 10162 | 6499 | 3663 | 448 | 6050 | 4036 | 2015 |
| | 92 | 14276 | 1999 | 12277 | 7852 | 4426 | 542 | 7310 | 4876 | 2434 |
| | 93 | 19811 | 2774 | 17037 | 10896 | 6141 | 752 | 10144 | 6766 | 3378 |
| | 94 | 19262 | 2697 | 16565 | 10594 | 5971 | 731 | 9863 | 6579 | 3284 |
| | 95 | 20703 | 2898 | 17805 | 11387 | 6418 | 786 | 10601 | 7071 | 3530 |
| | 96 | 15023 | 2103 | 12920 | 8263 | 4657 | 570 | 7693 | 5131 | 2561 |
| | 97 | 19236 | 2693 | 16543 | 10580 | 5963 | 730 | 9850 | 6570 | 3280 |
| | 98 | 15800 | 2212 | 13588 | 8690 | 4898 | 600 | 8090 | 5396 | 2694 |
| | 99 | 19208 | 2689 | 16519 | 10564 | 5954 | 729 | 9835 | 6560 | 3275 |
| | 100 | 17298 | 2422 | 14876 | 9514 | 5362 | 656 | 8857 | 5908 | 2949 |
| | 101 | 15387 | 2154 | 13233 | 8463 | 4770 | 584 | 7879 | 5255 | 2623 |
| D16 | 102 | 12502 | 2125 | 10502 | 7126 | 3376 | 520 | 6606 | 4682 | 1924 |
| | 103 | 13263 | 2255 | 11141 | 7560 | 3581 | 552 | 7008 | 4967 | 2041 |
| | 104 | 14805 | 2517 | 12436 | 8439 | 3997 | 616 | 7823 | 5544 | 2278 |
| | 105 | 13996 | 2379 | 11757 | 7978 | 3779 | 582 | 7395 | 5241 | 2154 |
| | 106 | 13202 | 2244 | 11090 | 7525 | 3565 | 549 | 6976 | 4944 | 2032 |
| | 107 | 13491 | 2293 | 11332 | 7690 | 3643 | 561 | 7129 | 5052 | 2076 |
| | 108 | 12282 | 2088 | 10317 | 7001 | 3316 | 511 | 6490 | 4599 | 1890 |
| | 109 | 12399 | 2108 | 10415 | 7067 | 3348 | 516 | 6552 | 4643 | 1908 |
| | 110 | 13586 | 2310 | 11412 | 7744 | 3668 | 565 | 7179 | 5088 | 2091 |
| | 111 | 11956 | 2033 | 10043 | 6815 | 3228 | 497 | 6317 | 4477 | 1840 |
| D9 | 112 | 13689 | 1369 | 12320 | 6571 | 5749 | 381 | 6190 | 3430 | 2760 |
| | 113 | 11181 | 1118 | 10063 | 5367 | 4696 | 311 | 5056 | 2802 | 2254 |
| | 114 | 17039 | 1704 | 15335 | 8179 | 7156 | 474 | 7704 | 4269 | 3435 |
| | 115 | 19429 | 1943 | 17486 | 9326 | 8160 | 541 | 8785 | 4868 | 3917 |
| | 116 | 20727 | 2073 | 18654 | 9949 | 8705 | 577 | 9372 | 5193 | 4179 |
| | 117 | 21352 | 2135 | 19217 | 10249 | 8968 | 594 | 9655 | 5350 | 4305 |
| | 118 | 21640 | 2164 | 19476 | 10387 | 9089 | 602 | 9785 | 5422 | 4363 |
| | 119 | 21473 | 2147 | 19326 | 10307 | 9019 | 598 | 9709 | 5380 | 4329 |
| | 120 | 22402 | 2240 | 20162 | 10753 | 9409 | 624 | 10129 | 5613 | 4516 |
| | 121 | 16240 | 1624 | 14616 | 7795 | 6821 | 452 | 7343 | 4069 | 3274 |
| | 122 | 18782 | 1878 | 16904 | 9015 | 7888 | 523 | 8492 | 4706 | 3786 |
| | 123 | 19036 | 1904 | 17132 | 9137 | 7995 | 530 | 8607 | 4770 | 3838 |
| | 124 | 15871 | 1587 | 14284 | 7618 | 6666 | 442 | 7176 | 3977 | 3200 |
| | 125 | 18379 | 1838 | 16541 | 8822 | 7719 | 512 | 8310 | 4605 | 3705 |
| D15 | 126 | 37580 | 3382 | 34198 | 18038 | 16159 | 1028 | 17010 | 9254 | 7757 |
| | 127 | 33857 | 3047 | 30810 | 16251 | 14559 | 926 | 15325 | 8337 | 6988 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 128 | 36205 | 3258 | 32947 | 17378 | 15568 | 991 | 16388 | 8915 | 7473 |
| | 129 | 36751 | 3308 | 33443 | 17640 | 15803 | 1006 | 16635 | 9050 | 7585 |
| | 130 | 36851 | 3317 | 33534 | 17688 | 15846 | 1008 | 16680 | 9074 | 7606 |
| | 131 | 34289 | 3086 | 31203 | 16459 | 14744 | 938 | 15521 | 8443 | 7077 |
| | 132 | 35477 | 3193 | 32284 | 17029 | 15255 | 971 | 16058 | 8736 | 7322 |
| D11 | 133 | 36384 | 5458 | 30926 | 20375 | 10551 | 1447 | 18928 | 13020 | 5909 |
| | 134 | 39168 | 5875 | 33293 | 21934 | 11359 | 1557 | 20377 | 14016 | 6361 |
| | 135 | 40138 | 6021 | 34117 | 22477 | 11640 | 1596 | 20881 | 14363 | 6518 |
| | 136 | 41000 | 6150 | 34850 | 22960 | 11890 | 1630 | 21330 | 14671 | 6658 |
| | 137 | 39471 | 5921 | 33550 | 22104 | 11447 | 1569 | 20534 | 14124 | 6410 |
| | 138 | 45504 | 6826 | 38678 | 25482 | 13196 | 1809 | 23673 | 16283 | 7390 |
| | 139 | 40872 | 6131 | 34741 | 22888 | 11853 | 1625 | 21263 | 14626 | 6638 |
| | 140 | 36872 | 5531 | 31341 | 20648 | 10693 | 1466 | 19182 | 13194 | 5988 |
| D7 | 141 | 14072 | 2111 | 11961 | 7880 | 4081 | 560 | 7321 | 5036 | 2285 |
| | 142 | 13852 | 2078 | 11774 | 7757 | 4017 | 551 | 7206 | 4957 | 2250 |
| | 143 | 18059 | 2709 | 15350 | 10113 | 5237 | 718 | 9395 | 6462 | 2933 |
| | 144 | 14633 | 2195 | 12438 | 8194 | 4244 | 582 | 7613 | 5236 | 2376 |
| | 145 | 14814 | 2222 | 12592 | 8296 | 4296 | 589 | 7707 | 5301 | 2406 |
| | 146 | 16839 | 2526 | 14313 | 9430 | 4883 | 670 | 8760 | 6026 | 2735 |
| | 147 | 15727 | 2359 | 13368 | 8807 | 4561 | 625 | 8182 | 5628 | 2554 |
| | 148 | 16522 | 2478 | 14044 | 9252 | 4791 | 657 | 8595 | 5912 | 2683 |
| | 149 | 17249 | 2587 | 14662 | 9659 | 5002 | 686 | 8974 | 6172 | 2801 |
| | 150 | 15524 | 2329 | 13195 | 8693 | 4502 | 617 | 8076 | 5555 | 2521 |
| | 151 | 15905 | 2386 | 13519 | 8907 | 4612 | 632 | 8274 | 5691 | 2583 |
| | 152 | 12831 | 1925 | 10906 | 7185 | 3721 | 510 | 6675 | 4591 | 2084 |
| | 153 | 14791 | 2219 | 12572 | 8283 | 4289 | 588 | 7695 | 5293 | 2402 |
| | 154 | 16111 | 2417 | 13694 | 9022 | 4672 | 641 | 8382 | 5765 | 2616 |
| | 155 | 14172 | 2126 | 12046 | 7936 | 4110 | 563 | 7373 | 5071 | 2302 |
| | 156 | 19247 | 2887 | 16360 | 10778 | 5582 | 765 | 10013 | 6887 | 3126 |
| | 157 | 14893 | 2234 | 12659 | 8340 | 4319 | 592 | 7748 | 5329 | 2419 |
| | 158 | 13527 | 2029 | 11498 | 7575 | 3923 | 538 | 7037 | 4841 | 2197 |
| | 159 | 13812 | 2072 | 11740 | 7735 | 4005 | 549 | 7186 | 4942 | 2243 |
| | 160 | 15125 | 2269 | 12856 | 8470 | 4386 | 601 | 7869 | 5412 | 2456 |
| | 161 | 11548 | 1732 | 9816 | 6467 | 3349 | 459 | 6008 | 4132 | 1875 |
| D22 | 162 | 8095 | 810 | 7286 | 3886 | 3400 | 225 | 3660 | 2028 | 1632 |
| | 163 | 5836 | 584 | 5252 | 2801 | 2451 | 162 | 2639 | 1462 | 1177 |
| | 164 | 8664 | 866 | 7798 | 4159 | 3639 | 241 | 3918 | 2171 | 1747 |
| | 165 | 6577 | 658 | 5919 | 3157 | 2762 | 183 | 2974 | 1648 | 1326 |
| | 166 | 7817 | 782 | 7035 | 3752 | 3283 | 218 | 3535 | 1959 | 1576 |
| | 167 | 6613 | 661 | 5952 | 3174 | 2777 | 184 | 2990 | 1657 | 1333 |
| D13 | 168 | 10260 | 1334 | 8824 | 5643 | 3181 | 389 | 5254 | 3504 | 1749 |
| | 169 | 10220 | 1329 | 8789 | 5621 | 3168 | 388 | 5233 | 3491 | 1743 |
| | 170 | 13035 | 1695 | 11210 | 7169 | 4041 | 495 | 6675 | 4452 | 2222 |
| | 171 | 16763 | 2179 | 14416 | 9220 | 5197 | 636 | 8583 | 5725 | 2858 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 172 | 15953 | 2074 | 13720 | 8774 | 4945 | 605 | 8169 | 5449 | 2720 |
| | 173 | 16451 | 2139 | 14148 | 9048 | 5100 | 624 | 8424 | 5619 | 2805 |
| | 174 | 9798 | 1274 | 8426 | 5389 | 3037 | 372 | 5017 | 3347 | 1671 |
| | 175 | 12537 | 1630 | 10782 | 6895 | 3886 | 476 | 6420 | 4282 | 2138 |
| | 176 | 18383 | 2390 | 15809 | 10111 | 5699 | 698 | 9413 | 6279 | 3134 |
| | 177 | 14463 | 1880 | 12438 | 7955 | 4484 | 549 | 7406 | 4940 | 2466 |
| | 178 | 17623 | 2291 | 15156 | 9693 | 5463 | 669 | 9024 | 6019 | 3005 |
| | 179 | 14932 | 1941 | 12842 | 8213 | 4629 | 567 | 7646 | 5100 | 2546 |
| | 180 | 16002 | 2080 | 13762 | 8801 | 4961 | 607 | 8194 | 5465 | 2728 |
| D20 | 181 | 12763 | 1149 | 11614 | 5999 | 5616 | 336 | 5663 | 3023 | 2639 |
| | 182 | 11214 | 1009 | 10205 | 5271 | 4934 | 295 | 4975 | 2656 | 2319 |
| | 183 | 7837 | 705 | 7132 | 3683 | 3448 | 206 | 3477 | 1856 | 1621 |
| | 184 | 8956 | 806 | 8150 | 4209 | 3941 | 236 | 3974 | 2121 | 1852 |
| | 185 | 9402 | 846 | 8556 | 4419 | 4137 | 247 | 4171 | 2227 | 1944 |
| | 186 | 9651 | 869 | 8782 | 4536 | 4246 | 254 | 4282 | 2286 | 1996 |
| | 187 | 11551 | 1040 | 10511 | 5429 | 5082 | 304 | 5125 | 2736 | 2389 |
| D12 | 188 | 18853 | 2262 | 16591 | 10181 | 6410 | 672 | 9509 | 6047 | 3461 |
| | 189 | 25103 | 3012 | 22091 | 13556 | 8535 | 895 | 12661 | 8052 | 4609 |
| | 190 | 25934 | 3112 | 22822 | 14004 | 8818 | 924 | 13080 | 8319 | 4761 |
| | 191 | 23047 | 2766 | 20281 | 12445 | 7836 | 821 | 11624 | 7393 | 4231 |
| | 192 | 23843 | 2861 | 20982 | 12875 | 8107 | 850 | 12025 | 7648 | 4378 |
| | 193 | 26312 | 3157 | 23155 | 14208 | 8946 | 938 | 13271 | 8440 | 4831 |
| | 194 | 24083 | 2890 | 21193 | 13005 | 8188 | 858 | 12147 | 7725 | 4422 |
| 21 | 195 | 24944 | 2993 | 21951 | 12971 | 8980 | 830 | 12141 | 7471 | 4670 |
| | 196 | 23335 | 2800 | 20535 | 12134 | 8401 | 777 | 11358 | 6989 | 4368 |
| | 197 | 23779 | 2853 | 20926 | 12365 | 8560 | 791 | 11574 | 7122 | 4451 |
| | 198 | 25071 | 3009 | 22062 | 13037 | 9026 | 834 | 12203 | 7509 | 4693 |
| | 199 | 23049 | 2766 | 20283 | 11985 | 8298 | 767 | 11218 | 6904 | 4315 |
| D19 | 200 | 10229 | 1330 | 8899 | 5319 | 3580 | 346 | 4973 | 3112 | 1862 |
| | 201 | 6188 | 804 | 5384 | 3218 | 2166 | 209 | 3009 | 1882 | 1126 |
| | 202 | 6868 | 893 | 5975 | 3571 | 2404 | 232 | 3339 | 2089 | 1250 |
| | 203 | 11191 | 1455 | 9736 | 5819 | 3917 | 378 | 5441 | 3404 | 2037 |
| D18 | 204 | 3469 | 2775 | 3191 | 1630 | 1561 | 90 | 1541 | 807 | 734 |
| | 205 | 3580 | 2864 | 3294 | 1683 | 1611 | 93 | 1590 | 833 | 757 |
| | 206 | 4126 | 3301 | 3796 | 1939 | 1857 | 107 | 1833 | 960 | 873 |
| | 207 | 3795 | 3036 | 3491 | 1784 | 1708 | 98 | 1686 | 883 | 803 |
| D17 | 208 | 21421 | 2356 | 19065 | 11353 | 7712 | 727 | 10627 | 6539 | 4087 |
| | 209 | 24887 | 2738 | 22149 | 13190 | 8959 | 844 | 12346 | 7598 | 4748 |
| | 210 | 17758 | 1953 | 15805 | 9412 | 6393 | 602 | 8809 | 5421 | 3388 |
| | 211 | 21706 | 2388 | 19318 | 11504 | 7814 | 736 | 10768 | 6626 | 4142 |
| D14 | 212 | 23374 | 3272 | 20102 | 12388 | 7713 | 830 | 11558 | 7470 | 4088 |
| | 213 | 23862 | 3341 | 20521 | 12647 | 7874 | 847 | 11800 | 7626 | 4173 |
| Total | | 4139007 | 531560 | 3611812 | 2210980 | 1400833 | 146895 | 2064085 | 1322052 | 742033 |

## State Preference survey for understanding users' behaviour regarding the proposed Bus Rapid Transit system in Jalalabad City

Name: ………….. Date: ……………………

**Part 1: Socioeconomic Characteristics**

| | | |
|---|---|---|
| Gender | Male | ☐ |
| | Female | ☐ |
| Occupation | Employment | ☐ |
| | Student | ☐ |
| | Others | ☐ |
| Car Ownership | Yes | ☐ |
| | No | ☐ |
| Age | 15-35 | ☐ |
| | 36-55 | ☐ |
| | 56-75 | ☐ |

**Part 2: Travel Features**

| | | |
|---|---|---|
| Driving License | Yes | ☐ |
| | No | ☐ |
| Travel Purpose | Work | ☐ |
| | Study | ☐ |
| | Other | ☐ |

**Part 3: Purposed Bus Rapid Transit System in Jalalabad City**

Please rate your desired Bus Rapid Transit system which is started from "Gulabad" to "Sayedabad" in Jalalabad city.

| Highly Dissatisfied | Dissatisfied | Satisfied | Highly Satisfied |
|---|---|---|---|
| **1** | **2** | **3** | **4** |

| NO | Travel Cost (Afg) | Travel Time (min) | Waiting Time (min) | Station Distance (m) | Walking Time to Station (min) | Station type | Air-Condition | Corridor Type | Level of Satisfaction 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 30 | 55 | 5 | 500-800 | 10 | Protected | Yes | Mixed | ☐ | ☐ | ☐ | ☐ |
| **2** | 40 | 35 | 15 | 800-1000 | 10 | Non-Protected | Yes | Mixed | ☐ | ☐ | ☐ | ☐ |
| **3** | 40 | 45 | 10 | 500-800 | 10 | Protected | No | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **4** | 10 | 35 | 5 | 500-800 | 5 | Non-Protected | No | Mixed | ☐ | ☐ | ☐ | ☐ |
| **5** | 20 | 35 | 8 | 500-800 | 10 | Protected | Yes | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **6** | 10 | 55 | 10 | 800-1000 | 10 | Protected | Yes | Mixed | ☐ | ☐ | ☐ | ☐ |
| **7** | 30 | 60 | 8 | 800-1000 | 10 | Non-Protected | No | Mixed | ☐ | ☐ | ☐ | ☐ |
| **8** | 30 | 35 | 15 | 800-1000 | 5 | Non-Protected | No | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **9** | 10 | 45 | 8 | 800-1000 | 5 | Non-Protected | Yes | Mixed | ☐ | ☐ | ☐ | ☐ |
| **10** | 30 | 45 | 15 | 500-800 | 5 | Protected | Yes | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **11** | 40 | 55 | 5 | 500-800 | 5 | Non-Protected | No | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **12** | 20 | 55 | 15 | 800-1000 | 5 | Protected | No | Mixed | ☐ | ☐ | ☐ | ☐ |
| **13** | 20 | 45 | 5 | 800-1000 | 10 | Non-Protected | No | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **14** | 10 | 60 | 15 | 500-800 | 10 | Protected | No | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **15** | 40 | 60 | 5 | 800-1000 | | Protected | Yes | Dedicated | ☐ | ☐ | ☐ | ☐ |
| **16** | 20 | 60 | 10 | 500-800 | 5 | Non-Protected | Yes | Mixed | ☐ | ☐ | ☐ | ☐ |

53

Figure A1: SP survey questionary form

Table A3: Trips by mode choice and level of compactness

| Des | Traffic zones | Trip by Walk | Trip by PT | Trip by car | Level of Compactness |
|---|---|---|---|---|---|
| D1 | 1.0 | 5893.0 | 5136.0 | 3687.0 | 3.4 |
| | 2.0 | 5518.0 | 4841.0 | 3451.0 | 2.6 |
| | 3.0 | 5250.0 | 4580.0 | 3278.0 | 3.5 |
| | 4.0 | 5351.0 | 4665.0 | 3352.0 | 5.1 |
| | 5.0 | 5562.0 | 4880.0 | 3482.0 | 2.5 |
| | 6.0 | 5162.0 | 4519.0 | 3234.0 | 1.8 |
| | 7.0 | 4951.0 | 4338.0 | 3089.0 | 5.2 |
| | 8.0 | 5763.0 | 5028.0 | 3620.0 | 2.6 |
| | 9.0 | 5099.0 | 4465.0 | 3197.0 | 4.6 |
| | 10.0 | 4730.0 | 4145.0 | 2958.0 | 4.0 |
| | 11.0 | 4935.0 | 4315.0 | 3077.0 | 2.7 |
| | 12.0 | 4901.0 | 4288.0 | 3048.0 | 4.3 |
| | 13.0 | 4473.0 | 3881.0 | 2803.0 | 1.9 |
| | 14.0 | 6325.0 | 5515.0 | 3961.0 | 6.0 |
| D2 | 15.0 | 7507.0 | 6573. | 4691.0 | 4.2 |
| | 16.0 | 7383.0 | 6454.0 | 4620.0 | 4.3 |
| | 17.0 | 9858.0 | 8604.0 | 6160.0 | 5.1 |
| | 18.0 | 7515.0 | 6572.0 | 4691.0 | 4.2 |
| | 19.0 | 7922.0 | 6915.0 | 4970.0 | 4.5 |
| | 20.0 | 6937.0 | 6071.0 | 4340.0 | 2.9 |
| | 21.0 | 7026.0 | 6143.0 | 4402.0 | 5.4 |
| | 22.0 | 7422.0 | 6494.0 | 4631.0 | 4.2 |
| | 23.0 | 6193.0 | 5406.0 | 3877.0 | 3.8 |
| | 24.0 | 8420.0 | 7383.0 | 5269.0 | 6.5 |
| | 25.0 | 6238.0 | 5444.0 | 3915.0 | 4.6 |
| D3 | 26.0 | 7121.0 | 6227.0 | 4459.0 | 0.0 |
| | 27.0 | 6836.0 | 5976.0 | 4283.0 | -2.4 |
| | 28.0 | 7800.0 | 6807.0 | 4883.0 | -2.1 |
| | 29.0 | 7362.0 | 6445.0 | 4599.0 | 0.1 |
| | 30.0 | 6599.0 | 5784.0 | 4120.0 | 0.2 |
| | 31.0 | 6545.0 | 5742.0 | 4102.0 | -3.4 |
| | 32.0 | 6163.0 | 5375.0 | 3858.0 | 0.5 |
| | 33.0 | 5681.4 | 5268.6 | 6049.7 | -0.6 |
| | 34.0 | 3898.3 | 3918.4 | 6128.3 | -0.8 |
| | 35.0 | 6128.0 | 5348.0 | 3843.0 | -2.0 |
| | 36.0 | 4318.9 | 4012.2 | 4619.9 | -0.2 |

| | | | | | |
|---|---|---|---|---|---|
| | 37.0 | 5708.0 | 4984.0 | 3569.0 | -2.8 |
| D4 | 38.0 | 6611.0 | 5795.0 | 4141.0 | -0.8 |
| | 39.0 | 5991.0 | 5249.0 | 3764.0 | 2.7 |
| | 40.0 | 5852.0 | 5105.0 | 3672.0 | -1.9 |
| | 41.0 | 5464.0 | 4766.0 | 3413.0 | 0.0 |
| | 42.0 | 6107.3 | 5651.1 | 6527.6 | 0.4 |
| | 43.0 | 6756.0 | 5918.0 | 4213.0 | 2.2 |
| | 44.0 | 6622.0 | 5783.0 | 4144.0 | 2.9 |
| | 45.0 | 6523.0 | 5720.0 | 4097.0 | 2.6 |
| | 46.0 | 7283.0 | 6352.0 | 4555.0 | 1.1 |
| | 47.0 | 6842.0 | 5982.0 | 4267.0 | -0.6 |
| | 48.0 | 7052.0 | 6161.0 | 4412.0 | 0.7 |
| | 49.0 | 7349.0 | 6417.0 | 4586.0 | -0.8 |
| | 50.0 | 7081.0 | 6191.0 | 4431.0 | 1.8 |
| | 51.0 | 7948.0 | 6948.0 | 4983.0 | -1.9 |
| | 52.0 | 7273.0 | 6343.0 | 4556.0 | -0.9 |
| D5 | 53.0 | 5883.5 | 5889.6 | 9249.9 | 0.1 |
| | 54.0 | 5781.3 | 5775.2 | 9085.5 | -0.6 |
| | 55.0 | 12162 | 10645 | 7612.0 | -2.2 |
| | 56.0 | 8372.7 | 8368.0 | 13166 | -1.9 |
| | 57.0 | 7560.0 | 6609.0 | 4726.0 | 1.8 |
| | 58.0 | 8088.0 | 7066.0 | 5059.0 | -1.4 |
| | 59.0 | 4705.4 | 4710.4 | 7377.2 | 1.4 |
| D6 | 60.0 | 5868.0 | 5120.0 | 3681.0 | -0.2 |
| | 61.0 | 6039.0 | 5273.0 | 3787.0 | 2.3 |
| | 62.0 | 5744.0 | 5015.0 | 3596.0 | -2.3 |
| | 63.0 | 3891.3 | 3591.9 | 4164.4 | -2.9 |
| | 64.0 | 4947.0 | 4567.5 | 5288.3 | -0.4 |
| | 65.0 | 6633.0 | 5812.0 | 4136.0 | -2.1 |
| | 66.0 | 6439.0 | 5642.0 | 4028.0 | -1.0 |
| | 67.0 | 6308.0 | 5509.0 | 3952.0 | -1.0 |
| | 68.0 | 6118.0 | 5339.0 | 3835.0 | -2.6 |
| | 69.0 | 3851.4 | 3558.6 | 4117.8 | 1.5 |
| | 70.0 | 3564.4 | 3568.8 | 5612.8 | 1.5 |
| | 71.0 | 4134.9 | 4129.6 | 6513.5 | -1.1 |
| | 72.0 | 3275.3 | 3284.0 | 5157.7 | -2.6 |
| | 73.0 | 4132.1 | 4121.6 | 6505.3 | -1.4 |
| | 74.0 | 6044.0 | 5285.0 | 3798.0 | -0.2 |
| D10 | 75.0 | 7139.0 | 6255.0 | 4476.0 | -0.1 |

| | | | | | |
|---|---|---|---|---|---|
| | 76.0 | 7085.0 | 6210.0 | 4443.0 | 3.0 |
| | 77.0 | 6358.0 | 5895.9 | 6780.7 | 0.6 |
| | 78.0 | 5261.5 | 4872.6 | 5626.6 | 1.2 |
| | 79.0 | 7949.0 | 6931.0 | 4985.0 | -0.9 |
| | 80.0 | 8508.0 | 7434.0 | 5315.0 | -0.1 |
| | 81.0 | 6649.6 | 6150.6 | 7097.6 | 0.6 |
| | 82.0 | 8761.0 | 7659.0 | 5471.0 | 1.1 |
| | 83.0 | 8523.0 | 7444.0 | 5328.0 | 0.9 |
| | 84.0 | 7214.0 | 6688.8 | 7696.9 | 0.8 |
| | 85.0 | 7625.0 | 6657.0 | 4772.0 | 1.3 |
| D8 | 86.0 | 3936.1 | 3928.8 | 6175.1 | -0.6 |
| | 87.0 | 4312.7 | 4290.4 | 6772.9 | -2.0 |
| | 88.0 | 5026.0 | 5018.4 | 7896.6 | -1.6 |
| | 89.0 | 3938.2 | 3944.8 | 6187.0 | -1.8 |
| | 90.0 | 4163.6 | 4159.2 | 6557.2 | 1.9 |
| | 91.0 | 5143.4 | 4757.4 | 5495.6 | -0.7 |
| | 92.0 | 5610.0 | 5190.3 | 5988.1 | 3.2 |
| | 93.0 | 5860.0 | 5125.0 | 3667.0 | 2.8 |
| | 94.0 | 6155.0 | 5380.0 | 3871.0 | -0.3 |
| | 95.0 | 5869.0 | 5142.0 | 3673.0 | -0.1 |
| | 96.0 | 3674.3 | 3677.6 | 5779.1 | 0.1 |
| | 97.0 | 4148.2 | 4137.6 | 6525.2 | 0.0 |
| | 98.0 | 3801.0 | 3794.4 | 5973.6 | 0.1 |
| | 99.0 | 5689.0 | 4964.0 | 3546.0 | 4.8 |
| | 100.0 | 4181.8 | 4180.8 | 6598.4 | 4.1 |
| | 101.0 | 4027.1 | 4020.0 | 6328.9 | 0.1 |
| D16 | 102.0 | 6520.0 | 5703.0 | 4075.0 | -1.0 |
| | 103.0 | 5360.0 | 4678.0 | 3360.0 | -1.9 |
| | 104.0 | 5101.0 | 4472.0 | 3191.0 | -0.9 |
| | 105.0 | 3201.8 | 3189.6 | 5048.6 | -2.5 |
| | 106.0 | 3250.8 | 3238.4 | 5123.8 | -2.5 |
| | 107.0 | 4020.1 | 4022.4 | 6324.5 | -1.6 |
| | 108.0 | 5288.0 | 4626.0 | 3309.0 | -1.8 |
| | 109.0 | 4657.0 | 4056.0 | 2924.0 | -1.9 |
| | 110.0 | 5128.0 | 4487.0 | 3203.0 | -3.3 |
| | 111.0 | 3362.1 | 3372.0 | 5285.9 | -2.4 |
| D9 | 112.0 | 6937.0 | 6071.0 | 4340.0 | -1.1 |
| | 113.0 | 5635.0 | 4933.0 | 3515.0 | 0.2 |
| | 114.0 | 5754.0 | 5027.0 | 3592.0 | 2.9 |

| | | | | | |
|---|---|---|---|---|---|
| | 115. | 5951.0 | 5194.0 | 3722.0 | 0.4 |
| | 116.0 | 4855.2 | 4519.8 | 5184.1 | 2.3 |
| | 117.0 | 4170.6 | 4161.6 | 6542.8 | 2.9 |
| | 118.0 | 4027.8 | 4018.4 | 6328.8 | 3.0 |
| | 119.0 | 5294.0 | 4640.0 | 3318.0 | -2.3 |
| | 120.0 | 4710.0 | 4109.0 | 2959.0 | 1.4 |
| | 121.0 | 5669.0 | 4943.0 | 3551.0 | -1.9 |
| | 122.0 | 6466.0 | 5981.4 | 6887.0 | 0.2 |
| | 123.0 | 5470.6 | 5061.6 | 5836.0 | 0.4 |
| | 124.0 | 6819.0 | 5968.0 | 4260.0 | -3.0 |
| | 125.0 | 5884.2 | 5871.2 | 9238.6 | -1.0 |
| D15 | 126.0 | 11337.0 | 9905.0 | 7082.0 | -0.7 |
| | 127.0 | 6944.0 | 6932.0 | 10919.0 | -0.5 |
| | 128.0 | 9543.0 | 8335.0 | 5971.0 | -0.2 |
| | 129.0 | 6965.0 | 6956.0 | 10955.0 | -1.6 |
| | 130.0 | 6267.8 | 6276.0 | 9853.2 | -0.7 |
| | 131.0 | 9385.7 | 8692.2 | 10008.0 | -1.3 |
| | 132.0 | 9251.9 | 9240.0 | 14536.1 | -2.0 |
| D11 | 133.0 | 7165.9 | 7163.2 | 11260.9 | 1.6 |
| | 134.0 | 6606.6 | 6601.6 | 10376.8 | -0.7 |
| | 135.0 | 11909.0 | 10398.0 | 7451.0 | 3.5 |
| | 136.0 | 13034.0 | 11406.0 | 8144.0 | 3.2 |
| | 137.0 | 9636.2 | 9625.6 | 15150.2 | -0.9 |
| | 138.0 | 7959.0 | 7963.2 | 12497.8 | 3.4 |
| | 139.0 | 12824.0 | 11218.0 | 8030.0 | 2.4 |
| | 140.0 | 6855.3 | 6349.5 | 7319.0 | 0.4 |
| D7 | 141.0 | 5704.0 | 5010.0 | 3559.0 | 2.1 |
| | 142.0 | 5586.0 | 4893.0 | 3484.0 | 1.9 |
| | 140 | 5196.0 | 4557.0 | 3248.0 | 4.5 |
| | 144.0 | 6027.0 | 5263.0 | 3786.0 | 1.0 |
| | 145.0 | 6268.0 | 5476.0 | 3931.0 | 0.5 |
| | 146.0 | 4749.0 | 4163.0 | 2956.0 | 4.5 |
| | 147.0 | 4224.0 | 3677.0 | 2666.0 | 2.7 |
| | 148.0 | 4605.0 | 4036.0 | 2889.0 | -0.6 |
| | 149.0 | 4698.0 | 4118.0 | 2922.0 | 1.6 |
| | 150.0 | 4562.0 | 3983.0 | 2874.0 | 1.6 |
| | 151.0 | 4298.0 | 3739.0 | 2699.0 | -0.7 |
| | 152.0 | 3518.2 | 3249.0 | 3775.4 | -0.2 |
| | 153.0 | 4364.0 | 3792.0 | 2731.0 | -0.5 |

| | | | | | |
|---|---|---|---|---|---|
| | 154.0 | 4413.0 | 3834.0 | 2764.0 | 0.7 |
| | 155.0 | 4542.0 | 3962.0 | 2861.0 | -0.5 |
| | 156.0 | 4069.8 | 3771.0 | 4310.7 | 0.2 |
| | 157.0 | 3005.8 | 2984.8 | 4742.4 | -1.1 |
| | 158.0 | 3575.1 | 3292.2 | 3839.6 | 1.7 |
| | 159.0 | 2884.7 | 2891.2 | 4559.1 | -3.3 |
| | 160.0 | 3306.8 | 3316.0 | 5201.2 | -2.6 |
| | 161.0 | 3628.1 | 3608.8 | 5707.1 | -1.9 |
| D22 | 162.0 | 3336.2 | 3346.4 | 5216.4 | -1.9 |
| | 163.0 | 3027.5 | 3006.4 | 4760.1 | -3.4 |
| | 164.0 | 2961.7 | 2947.2 | 4674.1 | -2.5 |
| | 165.0 | 3059.0 | 3036.0 | 4815.0 | -1.9 |
| | 166.0 | 2758.7 | 2757.6 | 4340.7 | -3.5 |
| | 167.0 | 3175.9 | 3167.2 | 5003.9 | 0.1 |
| D13 | 168.0 | 3447.6 | 3182.4 | 3687.8 | 0.0 |
| | 169.0 | 3908.0 | 3414.0 | 2426.0 | -0.1 |
| | 170.0 | 2776.9 | 2764.8 | 4368.3 | -0.9 |
| | 171.0 | 2843.4 | 2834.4 | 4472.2 | 0.8 |
| | 172.0 | 3712.0 | 3414.6 | 3978.2 | 0.1 |
| | 173.0 | 3380.0 | 2978.0 | 2128.0 | -0.6 |
| | 174.0 | 3156.1 | 2941.2 | 3354.2 | 0.3 |
| | 175.0 | 3227.5 | 3017.7 | 3442.5 | -1.6 |
| | 176.0 | 2759.4 | 2740.8 | 4325.8 | 0.8 |
| | 177.0 | 3238.5 | 3031.2 | 3453.7 | -2.9 |
| | 178.0 | 3215.8 | 3203.2 | 5066.0 | -2.0 |
| | 179.0 | 2643.9 | 2677.6 | 4149.5 | -2.7 |
| | 180.0 | 2631.3 | 2667.2 | 4126.5 | -0.7 |
| D20 | 181.0 | 2776.9 | 2755.2 | 4358.9 | -2.8 |
| | 182.0 | 2519.3 | 2490.4 | 3960.3 | -2.7 |
| | 183.0 | 2589.3 | 2597.6 | 4074.1 | -3.5 |
| | 184.0 | 3070.2 | 3072.8 | 4806.0 | -2.9 |
| | 185.0 | 3087.0 | 3096.8 | 4829.2 | -3.2 |
| | 186.0 | 3174.5 | 3179.2 | 5010.3 | -3.1 |
| | 187.0 | 3621.8 | 3599.2 | 5695.0 | 3.4 |
| D12 | 188.0 | 3854.2 | 3854.4 | 6050.4 | -1.0 |
| | 189.0 | 4309.2 | 4307.2 | 6798.6 | -1.2 |
| | 190.0 | 3356.5 | 3358.4 | 5278.1 | -1.8 |
| | 191.0 | 5349.4 | 5359.2 | 8404.4 | -2.8 |
| | 192.0 | 4710.3 | 4724.8 | 7402.9 | 0.2 |

| | | | | | |
|---|---|---|---|---|---|
| | 193.0 | 5485.2 | 5473.6 | 8626.2 | -2.1 |
| | 194.0 | 3653.3 | 3651.2 | 5740.5 | -2.7 |
| 21 | 195.0 | 3987.9 | 3979.2 | 6266.9 | -4.3 |
| | 196.0 | 3354.4 | 3360.0 | 5249.6 | -4.4 |
| | 197.0 | 3674.3 | 3673.6 | 5758.1 | -4.4 |
| | 198.0 | 4193.0 | 4204.0 | 6598.0 | -4.2 |
| | 199.0 | 3684.1 | 3685.6 | 5774.3 | -3.2 |
| D19 | 200.0 | 3542.0 | 3529.6 | 5567.4 | -1.0 |
| | 201.0 | 3464.3 | 3465.6 | 5429.1 | -4.9 |
| | 202.0 | 3584.0 | 3584.8 | 5636.2 | -1.5 |
| | 203.0 | 3536.4 | 3521.6 | 5563.0 | -1.2 |
| D18 | 204.0 | 2342.2 | 2352.8 | 3692.0 | -3.5 |
| | 205.0 | 2447.9 | 2424.0 | 3857.1 | -1.7 |
| | 206.0 | 2202.2 | 2207.2 | 3444.6 | -3.6 |
| D17 | 207.0 | 2416.4 | 2402.4 | 3804.2 | -2.0 |
| | 208.0 | 3565.8 | 3560.8 | 5599.4 | -1.6 |
| | 209.0 | 4316.9 | 4308.8 | 6795.3 | -2.0 |
| | 210.0 | 4046.0 | 4031.2 | 6350.8 | -1.2 |
| | 211.0 | 3773.7 | 3756.0 | 5945.3 | -2.7 |
| D14 | 212.0 | 3398.5 | 3396.8 | 5315.7 | 0.8 |
| | 213.0 | 3215.8 | 3203.2 | 5066.0 | -2.0 |

Table A3: The collected data

| Observed Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| District No | TRZs No | Dependent Variables | | Independent Variables | | | | | |
| | | Trip Generation | Trip Attraction | Car Ownership | Student | Employee | Population | Pop Density | Area (ha) |
| D1 | 1 | 46 | 70 | 47 | 49 | 43 | 73 | 6.08 | 12 |
| | 2 | 76 | 97 | 42 | 56 | 40 | 159 | 8.37 | 19 |
| | 3 | 80 | 105 | 53 | 66 | 57 | 104 | 2.37 | 44 |
| | 4 | 64 | 75 | 33 | 52 | 36 | 157 | 6.54 | 24 |
| | 5 | 68 | 88 | 46 | 48 | 39 | 153 | 19.14 | 8 |
| | 6 | 64 | 82 | 49 | 44 | 44 | 103 | 11.49 | 9 |
| | 7 | 78 | 99 | 39 | 45 | 40 | 106 | 1.66 | 64 |
| | 8 | 110 | 82 | 44 | 38 | 30 | 125 | 8.36 | 15 |
| | 9 | 71 | 89 | 36 | 43 | 23 | 173 | 3.27 | 53 |
| | 10 | 77 | 109 | 27 | 38 | 29 | 108 | 3.00 | 36 |
| | 11 | 76 | 107 | 37 | 61 | 29 | 106 | 4.83 | 22 |
| | 12 | 64 | 83 | 35 | 46 | 25 | 106 | 2.87 | 37 |
| | 13 | 65 | 94 | 18 | 53 | 26 | 106 | 1.28 | 83 |
| | 14 | 85 | 104 | 45 | 62 | 73 | 225 | 8.34 | 27 |
| D2 | 15 | 192 | 228 | 100 | 85 | 95 | 219 | 15.65 | 14 |
| | 16 | 171 | 221 | 79 | 89 | 88 | 324 | 5.40 | 60 |
| | 17 | 155 | 192 | 49 | 112 | 64 | 204 | 2.84 | 72 |
| | 18 | 147 | 193 | 100 | 51 | 70 | 192 | 5.80 | 33 |
| | 19 | 162 | 207 | 85 | 81 | 71 | 206 | 4.79 | 43 |
| | 20 | 161 | 204 | 75 | 81 | 90 | 201 | 5.16 | 39 |
| | 21 | 102 | 135 | 68 | 83 | 59 | 190 | 4.23 | 45 |
| | 22 | 112 | 147 | 85 | 53 | 60 | 256 | 2.61 | 98 |
| | 23 | 114 | 135 | 62 | 67 | 62 | 224 | 1.84 | 122 |
| | 24 | 71 | 86 | 109 | 65 | 79 | 220 | 5.36 | 41 |
| | 25 | 133 | 157 | 52 | 90 | 48 | 264 | 2.20 | 120 |
| D3 | 26 | 66 | 100 | 41 | 75 | 51 | 155 | 17.26 | 9 |
| | 27 | 198 | 195 | 26 | 56 | 67 | 333 | 19.61 | 17 |
| | 28 | 115 | 110 | 51 | 35 | 70 | 220 | 7.59 | 29 |
| | 29 | 189 | 180 | 63 | 58 | 63 | 297 | 6.46 | 46 |
| | 30 | 190 | 140 | 69 | 43 | 67 | 228 | 3.51 | 65 |
| | 31 | 95 | 108 | 46 | 59 | 20 | 161 | 3.75 | 43 |
| | 32 | 111 | 114 | 61 | 39 | 53 | 177 | 1.68 | 105 |
| | 33 | 118 | 109 | 55 | 56 | 49 | 266 | 1.71 | 156 |
| | 34 | 115 | 138 | 34 | 34 | 49 | 178 | 0.85 | 211 |
| | 35 | 83 | 99 | 68 | 47 | 56 | 133 | 3.90 | 34 |
| | 36 | 108 | 117 | 33 | 46 | 41 | 177 | 1.14 | 155 |
| | 37 | 89 | 98 | 44 | 31 | 29 | 149 | 2.36 | 63 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| D4 | 38 | 86 | 96 | 46 | 49 | 37 | 147 | 1.72 | 85 |
| | 39 | 115 | 110 | 51 | 43 | 43 | 182 | 3.43 | 53 |
| | 40 | 83 | 94 | 32 | 38 | 32 | 139 | 1.86 | 75 |
| | 41 | 154 | 109 | 37 | 24 | 30 | 259 | 2.38 | 109 |
| | 42 | 232 | 162 | 57 | 38 | 34 | 271 | 1.40 | 193 |
| | 43 | 214 | 134 | 66 | 56 | 45 | 448 | 6.05 | 74 |
| | 44 | 123 | 119 | 51 | 31 | 57 | 338 | 4.23 | 80 |
| | 45 | 131 | 127 | 71 | 50 | 45 | 331 | 3.28 | 101 |
| | 46 | 216 | 147 | 51 | 48 | 31 | 453 | 10.53 | 43 |
| | 47 | 174 | 108 | 43 | 46 | 32 | 282 | 13.44 | 21 |
| | 48 | 109 | 120 | 54 | 34 | 42 | 277 | 4.26 | 65 |
| | 49 | 203 | 153 | 57 | 28 | 49 | 290 | 7.25 | 40 |
| | 50 | 136 | 135 | 55 | 51 | 47 | 236 | 3.86 | 61 |
| | 51 | 83 | 101 | 18 | 48 | 38 | 444 | 4.88 | 91 |
| | 52 | 140 | 122 | 133 | 28 | 66 | 134 | 1.76 | 76 |
| D5 | 53 | 284 | 188 | 146 | 80 | 101 | 444 | 0.48 | 929 |
| | 54 | 304 | 162 | 81 | 82 | 115 | 274 | 1.11 | 248 |
| | 55 | 424 | 201 | 97 | 102 | 71 | 534 | 4.01 | 133 |
| | 56 | 539 | 282 | 104 | 71 | 114 | 617 | 0.73 | 849 |
| | 57 | 216 | 158 | 114 | 68 | 108 | 222 | 2.58 | 86 |
| | 58 | 252 | 152 | 54 | 101 | 84 | 441 | 5.59 | 79 |
| | 59 | 296 | 150 | 25 | 48 | 52 | 306 | 0.48 | 635 |
| D6 | 60 | 83 | 115 | 18 | 65 | 29 | 135 | 1.83 | 74 |
| | 61 | 48 | 79 | 9 | 9 | 6 | 183 | 3.59 | 51 |
| | 62 | 56 | 87 | 30 | 12 | 69 | 103 | 1.78 | 58 |
| | 63 | 56 | 105 | 22 | 29 | 56 | 106 | 0.74 | 143 |
| | 64 | 76 | 86 | 22 | 27 | 53 | 131 | 0.77 | 170 |
| | 65 | 50 | 72 | 36 | 33 | 20 | 83 | 0.81 | 103 |
| | 66 | 56 | 96 | 77 | 48 | 74 | 199 | 2.49 | 80 |
| | 67 | 91 | 112 | 25 | 61 | 36 | 176 | 1.85 | 95 |
| | 68 | 75 | 108 | 40 | 31 | 66 | 120 | 1.71 | 70 |
| | 69 | 68 | 115 | 91 | 30 | 133 | 110 | 0.61 | 181 |
| | 70 | 55 | 83 | 10 | 18 | 43 | 199 | 0.08 | 2370 |
| | 71 | 55 | 98 | 36 | 41 | 65 | 117 | 0.15 | 793 |
| | 72 | 69 | 115 | 47 | 22 | 132 | 118 | 0.42 | 280 |
| | 73 | 68 | 100 | 31 | 66 | 58 | 121 | 0.34 | 358 |
| | 74 | 102 | 130 | 111 | 25 | 97 | 183 | 2.06 | 89 |
| D10 | 75 | 163 | 208 | 87 | 58 | 123 | 294 | 3.09 | 95 |
| | 76 | 265 | 221 | 41 | 66 | 61 | 452 | 3.53 | 128 |
| | 77 | 238 | 225 | 232 | 39 | 193 | 294 | 1.83 | 161 |
| | 78 | 185 | 181 | 39 | 89 | 57 | 312 | 1.90 | 164 |
| | 79 | 189 | 163 | 101 | 35 | 79 | 326 | 2.91 | 112 |
| | 80 | 319 | 290 | 59 | 60 | 60 | 525 | 4.30 | 122 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 81 | 195 | 168 | 241 | 49 | 188 | 324 | 1.98 | 164 |
| | 82 | 160 | 169 | 110 | 98 | 92 | 294 | 3.63 | 81 |
| | 83 | 209 | 206 | 79 | 80 | 43 | 354 | 8.23 | 43 |
| | 84 | 259 | 227 | 187 | 67 | 145 | 442 | 2.82 | 157 |
| | 85 | 187 | 210 | 64 | 79 | 56 | 304 | 3.42 | 89 |
| D8 | 86 | 46 | 95 | 29 | 11 | 53 | 96 | 0.42 | 227 |
| | 87 | 61 | 112 | 47 | 40 | 52 | 103 | 0.18 | 568 |
| | 88 | 90 | 122 | 99 | 46 | 66 | 162 | 0.70 | 233 |
| | 89 | 83 | 127 | 48 | 95 | 60 | 148 | 0.55 | 272 |
| | 90 | 82 | 85 | 68 | 36 | 67 | 139 | 0.54 | 258 |
| | 91 | 55 | 126 | 46 | 34 | 68 | 91 | 0.62 | 147 |
| | 92 | 54 | 126 | 60 | 56 | 74 | 96 | 0.55 | 175 |
| | 93 | 100 | 125 | 73 | 38 | 60 | 165 | 2.71 | 61 |
| | 94 | 103 | 128 | 61 | 33 | 66 | 166 | 1.47 | 113 |
| | 95 | 102 | 119 | 44 | 32 | 36 | 165 | 1.31 | 126 |
| | 96 | 63 | 103 | 52 | 26 | 44 | 107 | 0.38 | 278 |
| | 97 | 101 | 111 | 55 | 15 | 59 | 165 | 0.50 | 327 |
| | 98 | 73 | 96 | 51 | 34 | 66 | 127 | 0.62 | 204 |
| | 99 | 98 | 100 | 40 | 25 | 42 | 177 | 1.96 | 90 |
| | 100 | 82 | 122 | 67 | 36 | 67 | 140 | 0.23 | 604 |
| | 101 | 63 | 94 | 75 | 59 | 56 | 110 | 0.09 | 1196 |
| D16 | 102 | 48 | 107 | 70 | 44 | 51 | 83 | 3.19 | 26 |
| | 103 | 48 | 97 | 67 | 46 | 103 | 79 | 0.79 | 100 |
| | 104 | 62 | 100 | 43 | 65 | 63 | 110 | 2.16 | 51 |
| | 105 | 49 | 112 | 29 | 56 | 56 | 88 | 0.32 | 278 |
| | 106 | 49 | 110 | 30 | 48 | 59 | 96 | 0.19 | 514 |
| | 107 | 56 | 124 | 74 | 24 | 52 | 99 | 0.15 | 654 |
| | 108 | 49 | 115 | 64 | 20 | 52 | 83 | 0.89 | 93 |
| | 109 | 49 | 120 | 38 | 35 | 50 | 79 | 1.39 | 57 |
| | 110 | 53 | 93 | 45 | 33 | 45 | 110 | 2.39 | 46 |
| | 111 | 51 | 97 | 42 | 55 | 62 | 88 | 0.13 | 700 |
| D9 | 112 | 56 | 94 | 83 | 56 | 50 | 96 | 1.18 | 81 |
| | 113 | 42 | 84 | 71 | 72 | 77 | 99 | 2.47 | 40 |
| | 114 | 75 | 80 | 60 | 28 | 66 | 132 | 1.83 | 72 |
| | 115 | 105 | 141 | 70 | 31 | 61 | 169 | 2.26 | 75 |
| | 116 | 115 | 136 | 48 | 27 | 81 | 178 | 1.20 | 148 |
| | 117 | 115 | 117 | 44 | 43 | 76 | 176 | 0.86 | 205 |
| | 118 | 128 | 127 | 20 | 56 | 29 | 206 | 0.63 | 326 |
| | 119 | 128 | 146 | 31 | 53 | 30 | 197 | 2.67 | 74 |
| | 120 | 119 | 127 | 9 | 29 | 37 | 193 | 4.01 | 48 |
| | 121 | 70 | 150 | 16 | 31 | 40 | 304 | 5.73 | 53 |
| | 122 | 97 | 129 | 37 | 33 | 62 | 148 | 0.80 | 185 |
| | 123 | 94 | 134 | 17 | 78 | 30 | 148 | 1.03 | 144 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 124 | 69 | 126 | 5 | 36 | 39 | 103 | 1.00 | 103 |
| | 125 | 96 | 159 | 121 | 42 | 90 | 149 | 0.16 | 930 |
| D15 | 126 | 325 | 231 | 180 | 66 | 166 | 451 | 3.79 | 119 |
| | 127 | 282 | 186 | 138 | 85 | 170 | 449 | 1.15 | 391 |
| | 128 | 314 | 213 | 120 | 88 | 119 | 467 | 9.16 | 51 |
| | 129 | 317 | 221 | 80 | 76 | 65 | 496 | 0.51 | 971 |
| | 130 | 317 | 192 | 71 | 67 | 75 | 503 | 0.72 | 698 |
| | 131 | 288 | 180 | 125 | 85 | 92 | 478 | 3.25 | 147 |
| | 132 | 288 | 209 | 225 | 97 | 183 | 459 | 0.53 | 864 |
| D11 | 133 | 317 | 215 | 106 | 142 | 135 | 460 | 1.79 | 257 |
| | 134 | 416 | 242 | 61 | 126 | 101 | 488 | 1.05 | 464 |
| | 135 | 409 | 246 | 125 | 96 | 113 | 677 | 8.90 | 76 |
| | 136 | 498 | 278 | 166 | 116 | 179 | 599 | 6.88 | 87 |
| | 137 | 447 | 226 | 189 | 141 | 174 | 596 | 2.52 | 237 |
| | 138 | 582 | 312 | 143 | 89 | 140 | 482 | 1.29 | 373 |
| | 139 | 420 | 244 | 183 | 67 | 152 | 625 | 7.62 | 82 |
| | 140 | 314 | 226 | 28 | 166 | 42 | 523 | 2.83 | 185 |
| D7 | 141 | 53 | 131 | 22 | 25 | 29 | 96 | 2.33 | 41 |
| | 142 | 53 | 86 | 35 | 42 | 43 | 77 | 2.86 | 27 |
| | 143 | 83 | 121 | 19 | 49 | 25 | 155 | 3.03 | 51 |
| | 144 | 62 | 92 | 47 | 15 | 26 | 90 | 1.06 | 85 |
| | 145 | 57 | 81 | 56 | 22 | 29 | 92 | 1.36 | 68 |
| | 146 | 72 | 88 | 25 | 52 | 25 | 120 | 2.04 | 59 |
| | 147 | 65 | 78 | 9 | 32 | 23 | 105 | 3.40 | 31 |
| | 148 | 65 | 83 | 11 | 22 | 37 | 139 | 1.21 | 115 |
| | 149 | 66 | 68 | 24 | 24 | 37 | 120 | 2.22 | 54 |
| | 150 | 66 | 75 | 17 | 17 | 28 | 120 | 1.38 | 87 |
| | 151 | 66 | 80 | 6 | 11 | 13 | 120 | 1.36 | 88 |
| | 152 | 48 | 67 | 17 | 27 | 30 | 81 | 0.54 | 149 |
| | 153 | 57 | 72 | 21 | 25 | 24 | 95 | 1.16 | 82 |
| | 154 | 65 | 95 | 17 | 13 | 24 | 104 | 1.51 | 69 |
| | 155 | 56 | 74 | 30 | 18 | 34 | 89 | 1.04 | 86 |
| | 156 | 104 | 87 | 6 | 30 | 30 | 169 | 1.14 | 148 |
| | 157 | 56 | 95 | 15 | 28 | 15 | 96 | 0.43 | 224 |
| | 158 | 48 | 89 | 19 | 18 | 22 | 81 | 0.56 | 144 |
| | 159 | 52 | 84 | 18 | 12 | 19 | 76 | 0.15 | 489 |
| | 160 | 88 | 90 | 32 | 17 | 19 | 105 | 0.11 | 971 |
| | 161 | 79 | 63 | 34 | 28 | 28 | 146 | 0.61 | 240 |
| D22 | 162 | 80 | 65 | 23 | 10 | 24 | 136 | 0.16 | 869 |
| | 163 | 14 | 54 | 21 | 11 | 18 | 144 | 0.15 | 955 |
| | 164 | 21 | 53 | 26 | 10 | 17 | 130 | 0.12 | 1104 |
| | 165 | 16 | 78 | 21 | 21 | 16 | 149 | 0.04 | 3884 |
| | 166 | 16 | 42 | 10 | 12 | 12 | 137 | 0.17 | 795 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 167 | 14 | 50 | 31 | 24 | 33 | 132 | 0.35 | 374 |
| D13 | 168 | 35 | 62 | 26 | 42 | 31 | 59 | 0.31 | 191 |
| | 169 | 41 | 89 | 25 | 41 | 39 | 36 | 0.58 | 62 |
| | 170 | 48 | 55 | 20 | 20 | 30 | 61 | 0.23 | 266 |
| | 171 | 79 | 77 | 36 | 14 | 27 | 28 | 0.13 | 211 |
| | 172 | 73 | 82 | 48 | 12 | 42 | 30 | 0.17 | 177 |
| | 173 | 76 | 86 | 8 | 34 | 19 | 22 | 0.36 | 61 |
| | 174 | 33 | 58 | 13 | 20 | 22 | 50 | 0.33 | 153 |
| | 175 | 34 | 59 | 11 | 25 | 19 | 65 | 0.36 | 184 |
| | 176 | 38 | 59 | 12 | 17 | 22 | 73 | 0.27 | 269 |
| | 177 | 39 | 58 | 12 | 11 | 26 | 61 | 0.32 | 192 |
| | 178 | 85 | 108 | 25 | 24 | 22 | 105 | 0.26 | 410 |
| | 179 | 39 | 79 | 14 | 19 | 31 | 54 | 0.08 | 708 |
| | 180 | 39 | 60 | 15 | 31 | 4 | 55 | 0.03 | 1810 |
| D20 | 181 | 41 | 49 | 22 | 8 | 12 | 56 | 0.23 | 244 |
| | 182 | 44 | 42 | 5 | 10 | 2 | 59 | 0.06 | 1012 |
| | 183 | 24 | 38 | 19 | 9 | 14 | 36 | 0.04 | 1029 |
| | 184 | 29 | 45 | 10 | 7 | 5 | 39 | 0.03 | 1554 |
| | 185 | 26 | 45 | 7 | 3 | 1 | 50 | 0.08 | 618 |
| | 186 | 34 | 32 | 14 | 4 | 7 | 46 | 0.03 | 1770 |
| | 187 | 39 | 65 | 40 | 11 | 58 | 51 | 0.01 | 8242 |
| D12 | 188 | 200 | 91 | 53 | 48 | 57 | 142 | 0.53 | 269 |
| | 189 | 157 | 122 | 48 | 76 | 128 | 209 | 0.76 | 276 |
| | 190 | 174 | 124 | 31 | 71 | 91 | 107 | 0.22 | 494 |
| | 191 | 132 | 150 | 69 | 66 | 46 | 302 | 0.37 | 824 |
| | 192 | 135 | 148 | 71 | 55 | 75 | 208 | 0.39 | 536 |
| | 193 | 185 | 125 | 81 | 50 | 97 | 296 | 0.82 | 359 |
| | 194 | 158 | 133 | 7 | 57 | 4 | 307 | 0.40 | 763 |
| D21 | 195 | 174 | 134 | 28 | 5 | 8 | 301 | 0.29 | 1030 |
| | 196 | 132 | 150 | 11 | 10 | 6 | 353 | 0.53 | 663 |
| | 197 | 135 | 148 | 10 | 6 | 9 | 200 | 0.31 | 637 |
| | 198 | 185 | 125 | 14 | 3 | 8 | 271 | 0.13 | 2053 |
| | 199 | 158 | 131 | 11 | 18 | 10 | 201 | 0.10 | 2056 |
| D19 | 200 | 45 | 42 | 11 | 5 | 7 | 200 | 0.12 | 1667 |
| | 201 | 18 | 47 | 24 | 17 | 8 | 161 | 0.22 | 724 |
| | 202 | 21 | 51 | 33 | 17 | 38 | 166 | 0.04 | 4111 |
| | 203 | 39 | 50 | 43 | 36 | 39 | 130 | 0.02 | 7759 |
| D18 | 204 | 7 | 52 | 2 | 4 | 2 | 40 | 0.05 | 746 |
| | 205 | 5 | 33 | 2 | 2 | 3 | 60 | 0.12 | 516 |
| | 206 | 8 | 53 | 1 | 2 | 2 | 35 | 0.04 | 970 |
| | 207 | 8 | 48 | 11 | 1 | 7 | 34 | 0.03 | 1194 |
| D17 | 208 | 103 | 107 | 24 | 24 | 28 | 154 | 0.14 | 1108 |
| | 209 | 149 | 135 | 33 | 38 | 38 | 254 | 0.29 | 877 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 210 | 95 | 89 | 43 | 28 | 39 | 190 | 0.32 | 589 |
| | 211 | 114 | 138 | 24 | 40 | 37 | 197 | 0.06 | 3048 |
| D14 | 212 | 123 | 150 | 14 | 45 | 45 | 158 | 0.05 | 3063 |
| | 213 | 135 | 140 | 35 | 41 | 39 | 154 | 0.02 | 7330 |

Table A4. Trip Generation in 213 trafic zones in Kabul city

| Zones | Trip Generation | Trip Attraction | Zones | Trip Generation | Trip Attraction | Zones | Trip Generation | Trip Attraction |
|---|---|---|---|---|---|---|---|---|
| 1 | 14175 | 13768 | 40 | 14287 | 13086 | 79 | 18758 | 16494 |
| 2 | 13515 | 13086 | 41 | 13218 | 13711 | 80 | 20134 | 18027 |
| 3 | 12740 | 13200 | 42 | 17314 | 15131 | 81 | 18646 | 16380 |
| 4 | 12929 | 13768 | 43 | 16513 | 13995 | 82 | 21058 | 15756 |
| 5 | 13597 | 13200 | 44 | 16101 | 14392 | 83 | 20776 | 14335 |
| 6 | 12476 | 13541 | 45 | 15919 | 13938 | 84 | 20620 | 14563 |
| 7 | 11960 | 13370 | 46 | 17678 | 14847 | 85 | 18587 | 14335 |
| 8 | 13997 | 13541 | 47 | 16769 | 13881 | 86 | 13678 | 13484 |
| 9 | 12224 | 13881 | 48 | 17292 | 14279 | 87 | 14955 | 13995 |
| 10 | 11300 | 13427 | 49 | 17808 | 15131 | 88 | 16977 | 16380 |
| 11 | 11842 | 13541 | 50 | 17177 | 14733 | 89 | 13585 | 14506 |
| 12 | 11723 | 13881 | 51 | 19492 | 14222 | 90 | 14539 | 13427 |
| 13 | 10714 | 13313 | 52 | 17719 | 14222 | 91 | 14584 | 14620 |
| 14 | 15407 | 13086 | 53 | 20635 | 15244 | 92 | 15544 | 17175 |
| 15 | 18023 | 15244 | 54 | 19767 | 15925 | 93 | 14146 | 14563 |
| 16 | 17400 | 17403 | 55 | 29428 | 17516 | 94 | 14825 | 14620 |
| 17 | 23529 | 16835 | 56 | 29684 | 15699 | 95 | 13790 | 16721 |
| 18 | 17815 | 16494 | 57 | 18594 | 14109 | 96 | 12758 | 13881 |
| 19 | 18713 | 16835 | 58 | 19667 | 15358 | 97 | 14443 | 14335 |
| 20 | 17158 | 16777 | 59 | 16620 | 14222 | 98 | 13218 | 13881 |
| 21 | 16873 | 15017 | 60 | 14064 | 14904 | 99 | 13864 | 13881 |
| 22 | 17993 | 14790 | 61 | 14777 | 13427 | 100 | 14506 | 14392 |
| 23 | 14884 | 14449 | 62 | 13945 | 14109 | 101 | 14201 | 13654 |
| 24 | 20538 | 14449 | 63 | 10951 | 14109 | 102 | 15800 | 13881 |
| 25 | 15188 | 13881 | 64 | 14198 | 13597 | 103 | 12921 | 13541 |
| 26 | 17255 | 14904 | 65 | 16379 | 13427 | 104 | 12302 | 13654 |
| 27 | 16624 | 13995 | 66 | 15845 | 13881 | 105 | 10899 | 14222 |
| 28 | 18824 | 15585 | 67 | 15545 | 13881 | 106 | 11166 | 13938 |
| 29 | 17871 | 14449 | 68 | 14981 | 13995 | 107 | 13856 | 14335 |
| 30 | 15901 | 15131 | 69 | 10936 | 14335 | 108 | 12847 | 14052 |
| 31 | 15919 | 14109 | 70 | 12654 | 13654 | 109 | 11200 | 13881 |
| 32 | 14999 | 13881 | 71 | 14665 | 13881 | 110 | 12420 | 13881 |
| 33 | 16235 | 14449 | 72 | 11441 | 13654 | 111 | 11671 | 13881 |
| 34 | 13534 | 13654 | 73 | 14472 | 13881 | 112 | 16910 | 13881 |
| 35 | 14903 | 14222 | 74 | 14673 | 14676 | 113 | 13678 | 13313 |
| 36 | 12331 | 13427 | 75 | 17095 | 15925 | 114 | 13882 | 13881 |
| 37 | 13893 | 13484 | 76 | 17118 | 15472 | 115 | 14164 | 14790 |
| 38 | 16038 | 14222 | 77 | 18134 | 15244 | 116 | 13637 | 14790 |
| 39 | 14647 | 13143 | 78 | 14713 | 16267 | 117 | 14075 | 16267 |

| Zones | Trip Generation | Trip Attraction | Zones | Trip Generation | Trip Attraction | Zones | Trip Generation | Trip Attraction |
|---|---|---|---|---|---|---|---|---|
| 118 | 13430 | 17403 | 157 | 10276 | 13768 | 196 | 11519 | 14335 |
| 119 | 12628 | 15017 | 158 | 10124 | 13427 | 197 | 12680 | 14279 |
| 120 | 11192 | 14563 | 159 | 9935 | 13370 | 198 | 14762 | 14222 |
| 121 | 13036 | 18197 | 160 | 11519 | 13654 | 199 | 12766 | 14563 |
| 122 | 18179 | 16948 | 161 | 12702 | 13484 | 200 | 12740 | 12689 |
| 123 | 15693 | 14392 | 162 | 11790 | 13086 | 201 | 12498 | 12689 |
| 124 | 16279 | 16380 | 163 | 10736 | 12859 | 202 | 13163 | 12689 |
| 125 | 20568 | 14676 | 164 | 10513 | 12689 | 203 | 12821 | 12745 |
| 126 | 27966 | 14335 | 165 | 10736 | 13654 | 204 | 8050 | 12689 |
| 127 | 24148 | 15925 | 166 | 9745 | 12632 | 205 | 8569 | 12291 |
| 128 | 23573 | 14449 | 167 | 11330 | 12689 | 206 | 7861 | 12745 |
| 129 | 24523 | 14449 | 168 | 9968 | 13086 | 207 | 8428 | 12632 |
| 130 | 21496 | 15925 | 169 | 9311 | 13541 | 208 | 12317 | 13881 |
| 131 | 26727 | 16267 | 170 | 9664 | 13029 | 209 | 15448 | 14733 |
| 132 | 32170 | 15472 | 171 | 9756 | 13427 | 210 | 14379 | 13597 |
| 133 | 25132 | 14335 | 172 | 10521 | 13597 | 211 | 13433 | 15017 |
| 134 | 23188 | 14904 | 173 | 7938 | 13654 | 212 | 11827 | 14676 |
| 135 | 29298 | 14449 | 174 | 8963 | 12973 | 213 | 12970 | 14563 |
| 136 | 32304 | 14449 | 175 | 9233 | 13029 | | | |
| 137 | 33591 | 16835 | 176 | 9501 | 13143 | | | |
| 138 | 27900 | 15699 | 177 | 9189 | 13029 | | | |
| 139 | 31391 | 16380 | 178 | 11103 | 13881 | | | |
| 140 | 19540 | 16040 | 179 | 9126 | 13484 | | | |
| 141 | 13289 | 16721 | 180 | 9211 | 12973 | | | |
| 142 | 13567 | 13541 | 181 | 9653 | 12689 | | | |
| 143 | 12046 | 16721 | 182 | 8721 | 12518 | | | |
| 144 | 14617 | 13881 | 183 | 8955 | 12576 | | | |
| 145 | 15281 | 13484 | 184 | 11096 | 12689 | | | |
| 146 | 11493 | 13427 | 185 | 11204 | 12745 | | | |
| 147 | 10154 | 13370 | 186 | 11515 | 12178 | | | |
| 148 | 11155 | 13427 | 187 | 13188 | 12689 | | | |
| 149 | 11434 | 13143 | 188 | 13726 | 13143 | | | |
| 150 | 11018 | 13484 | 189 | 15170 | 14335 | | | |
| 151 | 10365 | 13370 | 190 | 11511 | 14733 | | | |
| 152 | 10005 | 13313 | 191 | 18832 | 14335 | | | |
| 153 | 10606 | 13143 | 192 | 16509 | 14335 | | | |
| 154 | 10602 | 13825 | 193 | 19388 | 13995 | | | |
| 155 | 10985 | 13427 | 194 | 12684 | 14676 | | | |
| 156 | 11638 | 13370 | 195 | 13775 | 14733 | | | |

# References


Abbasi, M. H., Hosseinlou, M. H. & Fedaki, S. M. J. 2009. “An investigation of Bus Rapid Transit System (Tehran, Iran)”. Case Studies on Transport Policy, (In press).

Abdel-Aal, M. M. M. 2014. “Calibrating a trip distribution gravity model stratified by the trip purposes for the city of Alexandria”. Alexanria Engineering Journal, 53, 677-689.

Abdelghany, K. F., Mahmassani, H. S. & Abdelghany. A. F. 2007. “A Modeling Framework for Bus Rapid Transit Operations Evaluation and Service Planning”. Transportation Planning and Technology, 30, 571-591.

Aguilera, A., Wenglenski, S. & Proulhac, L. 2009. “Employment suburbanisation, reverse commuting and travel behaviour by residents of the central city in the Paris metropolitan area”. Transportation Research Part A, 43, 685-691.

Ahanchian, M., Gregg, J. S., Tattini, J. & Karlsson, K. B. 2019. “Analyzing effects of transport policies on travelers’ rational behaviour for modal shift in Denmark”. Case Studies on Transport Policy, 7, 849-861.

Alpkokin, P. & Ergun M. 2012. “Istanbul Metrobüs: first intercontinental bus rapid transit”. Journal of Transport Geography, 24, 58-66.

Ambarwati, L., Verhaeghe, R., Pel, A. J. & Arem, B. V. 2014. “Controlling urban sprawl with integrated approach of space-transport development strategies”. Procedia Social and Behavioral Sciences, 138, 679-694.

Ang-Olson, J. & Mahendra, A. 2011. “Cost/Benefit Analysis of Converting a Lane for Bus RapidTransit Phase II Evaluation and Methodology”. Trasnportation Research Board.

Arbury, J. 2000. From Urban Sprawl to Compact City – An analysis of urban growth management in Auckland”. Master Thesis.

Baghini, M. S., Ismail, A. Hafezi, M. H., Seifabad, O. K. & Almansob, R. A. 2013. “Bus Rapid Transit (BRT) system impacts to environmental quality”. Research Journal of Applied Sciences, Engineering and Technology, 7, 1344-1350.

Bajracharya, A. R. 2008. “Research Journal of Applied Sciences, Engineering and Technology”. ITC, Thesis.

Bates, J. 1988. “Econometric issues in stated preference analysis”. Journal of Transport and Economy Policy, 22, 59–69.

Ben-Akiva, M. & Morikawa, T. 2002. “Comparing ridership attraction of rail and bus”. Transport Policy, 9, 107-116.

Bibri, S. E., Krogstie, J. & Karrholm, M. 2020. Compact city planning and development: emerging practices and strategies for achieving the goals of sustainability”. Developments in the Built Environment, 4, 100021.

Boarnet, M. G. & Sarmiento, S. 1998. “Can Land-use policy really affect travel behaviour? A study of the link between non-work travel and Land-use characteristics”. Urban Studies, 35, 1155-1169.

Boontore, A., 2014. Sprawl and Distance Travelled: Evidence from European Metropolitan Areas. Thesis. University College London, 1-227

BrehenyM, Rookwood R, 1993,``Planning the sustainable city region'', in Planning for a Sustainable Environment Ed. A Blowers (Earthscan Publications, London), 150-189.

Burapatana, T. & Ross, W. 2007. “Bangkok: Suburbanizing and unsuitable”. Environment and Natural Resources Journal, 5, 59-68.

Burton, E. 2000. “The compact city: Just or just compact? A preliminary analysis”. Urban Studies, 37, 1969-2001.

Cain, A., Darido, G., Baltes, M. R., Rodriguez, P. & Barrios, J. C. 2007. “Applicability of

Callaghan, L. & Vincent, W. 2007. “Preliminary evaluation of Metro Orange Line Bus Rapid Transit project”. Transport Research Record 2034, 34-44.

Cascajo, R., Garcia-Martinez, A. & Monzon, A. 2017. “Stated preference survey for estimating passenger transfer penalties: design and application to Madrid”. European Transport Research Review, 42, 1-11.

Cervero, R. 2013. “Bus Rapid Transit (BRT): An efficient and competitive mode of public transport” ACEA.

Cervero, R. (2001). Efficient urbanisation: Economic performance and the shape of the metropolis. Urban Studies, 38(10), 1651-1671.

Cervero, R. 1998. “The Transit metropolis: A global inquiry”. Book, Available. https://trid.trb.org/view/538261.

Cervero, R. 1995. “Mixed Land-uses and commuting: Evidence from the American housing survey” Transportation Research-A, 30, 361-371.

Cervero, R. & Kockelman, K. 1997. “Travel demand and 3Ds: Density, Diversity and Design”. Transport Research-D, 2, 199-219.

Cherchi E, Hensher D. A. 2015. “Workshop synthesis: stated preference surveys and experimental design, an audit of the journey so far and future research perspectives”. Transport Res Proc 11:154–164.

Churchman, A. 1999. “Disentangling the concept of density”. Journal of Planning Literature, 13, 389-411.

Crane, R. 1996a. Cars and drivers in the new suburbs: Linking access to travel in nontraditional planning” Journal of the American Planning Association Winter, 62, 51-65.

Crane, R. 1996b. “On form versus function: Will the urbanism reduce it? Journal of planning

Education and Research, 15, 117-126.

Currie, G. 2006. “Bus Rapid Transit in Australasia: performance, Lessons learned and future”. Journal of Public Transportation, 1-22.

Currie, G., & Delbosc, A. (2011). Exploring the trip chaining behaviour of public transport users in Melbourne. Transportation, 38(1), 1-25.

Delmelle, E.C. 2012. “Evaluating the spatial equity of bus rapid transit-based accessibility patterns in a developing country: The case of Cali, Colombia”. Transport Policy, 20, 36-46.

Dempsey, N., Brown, C., Raman, S., Porta, S., Jenks, M., Jones, C. & Bramley, G. 2010. “Element of urban form”. Oxford Institute for Sustainable Development, Oxford Brookes University, Oxford, UK.

Dieleman, F. M., Dijst, M. & Burghouwt, G. 2002. “Urban form and travel behaviour: Micro-level household attributes and residential context”. Urban Studies, 39, 507-527.

Duarte, F. & Ultramari, C. 2012. Making public transport and housing match: accomplishments and failures of Curitiba's BRT, Journal of Urban Planning and Development, 138, 183-194.

EMBARQ 2009. “Social, environmental and economic impact of BRT system”. World Resources Institute.

Engelfriet, L. & Koomen, E. 2017. “The impact of urban form on commuting in large Chinese cities” Transportation.

Ewing, R., Pendall, R. & Chen, D. 2003, “Urban sprawl and transportation”. TRB Annual Meeting CD-ROM.

ESMAP 2014. “Formulating an urban transport policy”. International Bank for Reconstruction and Development, 1818. H Street, Washington DC.

Final Report, 2009. “The study for the development of the master plan for the Kabul metropolitan area in the Islamic Republic of Afghanistan”. RECS International Inc.

Fouracre, P. R., Allport, R. J. & Thomson, J. M. 1990. “The Performance and impact of rail mass transit in developing countries”. Transport and Road Research Laboratory.

Frank L. D. & Pivo G. 1994. “Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking”. Transportation Research Record Journal of the Transportation Research Board 1466, 44-52.

Gahlot, V., Swami, B. L., Parida, M. & Kalla, P. 2012. “User oriented planning of bus rapid transit corridor in GIS environment”. International Journal of Sustainable Built Environment, 1, 102-109.

Gennaio, M., Hersperger, A. M. & Burgi, M. 2009. “Containing urban sprawl—Evaluating effectiveness of urban growth boundaries set by the Swiss Land Use Plan” Land Use Policy, 26, 224-232.

Gim T. T. 2018. “An analysis of the relationship between land use and weekend travel: focusing on the internal capture of trips”. Sustainability 10, 425.

GPG 2016. “Good practice guide: Bus Rapid Transit system, C40 Cities Climate Leadership Group, North West Entrance, City-Gate House. London.

Hui. C. 2014. “Application study of All-or-Nothing assignment method for determination of logistic transport route in urban planning”. Computer Modelling and New Technologies, 18, 932-937.

Handy, S. L. 1992. “Regional versus local accessibility: Variations in suburban form and the effects on non-work travel. P.h.D Thesis, University of California at Berkeley.

Handy, S. 1996. “Methodology for exploring the link between urban form and travel behaviour”. Transportation Research-D, 1, 151-165.

Hensher, D. A. 1994. “Stated preference analysis of travel choices: the state of practice”.

Transportation, 21, 107–133.

Hensher, D. A., Rose, J. M. & Greene, W. H. 2005. “Applied choice analysis” Cambridge University Press.

Hensher, D. A. 1999. “A bus-based transit way or light rail? Continuing the saga on choice versus blind commitment”. Road and Transport Research, 8, 3–30.

Hensher, D. A. 2007. “Bus Transport: Economics, Policy and Planning”. Research in Transportation Economics, 18, Elsevier, Oxford.

Hidalgo, D. & Graftieaux, P. 2008. “Bus Rapid Transit system in Latin America and Asia: Results and difficulties in 11 cities” .Journal of the Transportation Research, 77-88.

Hidalgo, D., Pereira, L., Estupinan, N. & Jimenez, P. L. 2013. “TransMilenio BRT system in Bogota, high performance and positive impact-Main results of an ex-post evaluation”. Research in Transportation Economics, 39, 133-138.

Hoque, Md. M., Alam, D., Al Msmun, S. M. & Ahsan, H. M. 2013, “Bus Rapid Transit (BRT): What is it and Why Do We Need it for Dhaka”. Urban Public Transportation System, 369-380.

Hu, L., Sun, T. & Wang, L. 2018. “Evolving urban spatial structure and commuting patterns: A case study of Beijing, China” Transportation Research Part D, 59, 11-22.

Hu, L., Yang, J., Yang, T., Tu, Y. & Zhu, J. 20019. “Urban spatial structure and travel in China”. Journal of Planning Literature, 1-19.

Iatu, C., Munteanu, A., Boghinciuc, M., Cernesu, R. & Ibanesu. “The effects of transportation system on the urban sprawl process for the city of Iasi, Romania”. WIT Transactions on the Built Environment, 116. 291-301.

Ingvardson, J. B. & Nielsen, O. A. 2017. “Effects of new bus and rail rapid transit systems – an international review”. Transport Reviews, 1-21.

Jalal, E. & Mizokami, S. 2015. "Transportation policy for Kabul city: Short-Term and Long-Term". International Journal of Technical Research and Application, 32, 01-12.

`Javanmardi, M. 2005. "Mode choice modelling using personalized travel time and travel cost". National Center for Transit Research, University of South Florida.

Jenks, M., Burton E. & Williams, K. 1996. "The Compact City: A Sustainable Urban Form?". (Spon, London).

JICA 2004. "The study on urban transport master plan and feasibility study in HO Chi Minh metropolitan area". ALMEC Corporation.

Junyong, I. 2017. "Introduction of a pilot study", Korean Journal of Anaesthesiology, 70, 601–605.

JICA 2011. "Kabul Master Plan". REC International Inc, Yachiyo Engineering Co., Ltd.

Kain, J. F. & Fauth G. R. 1978. "The impact of urban development on auto ownership and transit use". Areuea Journal 6, 305-326.

Kakar, K. A. & Prasad C.S.R.K. 2019. "Introducing of mass rapid transit system (BRT) by using aggregate and disaggregate models". International Journal of Engineering and Advanced Technology 8, 2249-8958.

Mukoko, K.K., & Pulugurtha, S.S. (2019). Examining the influence of network, land use, and demographic characteristics to estimate the number of bicycle-vehicle crashes on urban roads. IATSS Research. https://doi.org/10.1016/j.iatssr.2019.04.001

Karakayaci, Z. 2016. "The concept of urban sprawl and its causes". The Journal of International Social Research 9, 815-818.

Kasanko M., Berredo J. I., Lavalle C., McCormick N., Demicheli L. & Sagris., Brezger. 2006. "Are European cities becoming dispersed? A comparative analysis of 15 European urban areas". Landscape and Urban Planning 77, 111-130.

Kitamura R., Mokhtarian P. L. & Laidet Laura. 1997. “A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area”. Transportation 24, 125-158.

Ko J., Kim D., AS.M.ASCE. & Etezady A. 2019. “Determinants of Bus Rapid Transit Ridership: System-Level Analysis”. Journal of Urban Planning and Development 145, 04019004.

Kockelman M. K. 1991. Travel behavior as a function of accessibility, land use mixing, and land use balance: evidence from the san francisco bay area. Master Thesis, University of California.

Levine, N., Wachs, M., & Shirazi, E. (2012). Crime at bus stops: A study of environmental factors. Journal of Public Transportation, 15(2), 23-43.

Li, G. & Li, F. 2019. “Urban sprawl in China: Differences and socioeconomic drivers”. Science of the Total Environment, 673, 367-377.

Li J., Song M. K., Li M. & Zhang W 2009. “Influence of urban form on travel behaviour in four neighbourhoods of Planning for bus rapid transit in single dedicated bus lane”. Transportation Research Record: J of the Transportation Research Board 2111, 76-82.

Liu S., Triantis K. P. & Sarangi S. 2010. “A framework for evaluating the dynamic impacts of a congestion pricing policy for a transportation socioeconomic system”. Transportation Research 44, 596-608.

Lopez Y. M., Alvarez A. E. & Walubita L. F. 2011. “Implementation of the bus rapid transit (BRT) system in Colombia”. GeoHunan International Conference 223, 206-2013.

Maeso-González E. & Pérez-Cerón P. 2014. “State of art of bus rapid transit transportation”. European Transport Research Review 6, 149-156

Mane, A. S., & Pulugurtha, S. S. (2020). Influence of proximal land use and network characteristics on link travel time. Journal of Urban Planning and Development, 146(3). https://doi.org/10.1061/(ASCE)UP.1943-5444.0000599.

Maparu T. S. & Pandit D. 2010. "A methodology for selection of bus rapid transit corridors: a case study of Kolkata". Institute of Town Planners, India 7, 21-36.

Mathew, S., & Pulugurtha, S. S. (2022). Assessing the effect of a light rail transit system on road traffic travel time reliability. Public Transport, 12(313-333). https://doi.org/10.1007/s12469-020-00234-0

McDonnell S., Susana F. & Frank C. 2009. "Bus priority provision and willingness to pay differentials resulting from modal choice and residential location: evidence from a stated choice survey". Journal of Transport Economics and Policy 43, 213-235.

Daniel McFadeen – Chaptr 4 (BOOK)

Modi K. B., Zala L. B., Umrigar F.S. & Desai T. A. 2011. "Transportation Planning Models: A Review"

Mooi, E. Sarstedt M., "A Concise Guide to Market Research Springer, Heidelberg, Germany, 2014.

Nakshi P. & Debnath A. K.2009. "Impact of built environment on mode choice to major destinations in Dhaka". Transportation Research Record 2675, 281-296.

Newman P. WG. & Kenworthy J. R. 1996. "The land use—transport connection: an overview". Land Use Policy 13, 1-22.

Nurdeen A., Rahmat R. A. & Ismail A. 2007. "Effect of transportation policy on model shift from private car to public transport in malaysia". Journal of Applied Sciences 7, 1013-1018.

OECD. (2020). Urban Transport Strategy Review. Organisation for Economic Co-operation and Development.

Ortuzar, J. D. & Willumsen, L. G. 1996. "Modelling Transport" A John Wiley and Sons, Ltd.

O'Sullivan, S., & Morrall, J. (1996). Walking distances to and from light-rail transit stations. Transportation Research Record, 1538(1), 19-26.

Owens S, 1992,``Energy, environmental sustainability and land-use planning'', in European Research in Regional Science 2. Sustainable Development and Urban Form Ed. M J Breheny (Pion, london) pp 79 ^ 105

Pahs M., Rohden M., Hampsten D., Gallant S. & Bertini R. L. 2002. "Door-to-door mobility: evaluating a bus rapid transit community transport concept". Journal of Public Transportation 5, 137-161.

Pan H., Shen Q. & Zhang M 2009. "Influence of urban form on travel behaviour in four neighbourhoods of shanghai". Urban Studies 46, 275-294.

Patankar V. M., Kumar R. & Tiwari G. 2010. "Impacts of Bus Rapid Transit Lanes on Traffic and Commuter Mobility". Journal of Urban Planning and Development, 133, 99-106.

Peak, M., Henke, C., and Wnuk, L. 2005. Bus rapid transit ridership analysis. Washington, D.C.: US Department of Transportation, Federal Transit Administration, Report FTACA-26-7068-2004.1.

Pulugurtha, S. S., Mishra, R., & Jayanthi, S. L. (2022). Does Transit Service Reliability Influence Ridership? Mineta Transportation Institute Publications. https://doi.org/10.31979/mti.2022.2118

Rambaud, F., Rabuel, S., and Crest, T. 2008. BHLS: The French BRT approach. Paris: Centre on Transport and Urbanism (Centru).

Santos G., Maoh H., Potoglou D. & Von Brunn, T. 2013. "Factors influencing modal split of commuting journeys in medium-size European cities". Journal of Transport Geography 30, 127-137.

Saddat S. A. R. & Lukumwena N. 2018. "Traffic congestion problem and possible solution in

Kabul city”. International Journal of Transport and Vehicle Engineering 12, 132-137

Satiennam T., Jaensirisak S., Satiennam W. & Detdamrong S. 2015. “Potential for modal shift by passenger car and motorcycle users towards Bus Rapid Transit (BRT) in an Asian developing city”. IATSS Research 2, 121-129.

Satiennam T., Fukuda A. & Oshima R. 2006. “A study on the introduction of bus rapid transit system in Asian developing cities: a case study on Bangkok metropolitan administration project”. IATSS Research 30, 59-60.

S. C. Wirasinghe , L. Kattan , M. M. Rahman , J. Hubbell , R. Thilakaratne & S. Anowar. 2012. “Bus rapid transit – a review”. International Journal of Urban Sciences., 17, 1-31.

Schwanen T. Dijist M. & Dieleman F M. 2004. “Policies for Urban Form and their Impact on Travel: The Netherlands Experience”. Urban Studies 41, 579-603.

Schwanen T. & Mokhtarian P. L. 2005. “What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods?”. Journal of Transport Geography 13, 83-99.

Shen Q., Chen P. & Pan H. 2016. “Factors affecting car ownership and mode choice in rail transit-supported suburbs of a large Chinese city”. Transportation Research Part A: Policy and Practice 94, 31-44.

Shirgaokar, M. 2016. “Expanding cities and vehicle use in India: differing impacts of built environment factors on scooter and car use in Mumbai”. Urban Studies 53, 3296-3316.

Stathakis, D. & Tsilimigkas G. 2013. “Applying urban compactness metrics on pan-european datasets”. Remote Sensing and Spatial Information Sciences XL, 127-132.

Steurer M. & Bayr C. 2020. “Measuring urban sprawl using land use data”. Land Use Policy 97, 104799.

Szolnoki G. & Hoffmann D. 2013. “Online, face-to-face and telephone surveys—Comparing different sampling methods in wine consumer research”. Wine Economics and Policy, 2, 57-66.

Tian Li., Li Y., Yan Y. & Wang B. 2013. “Measuring urban sprawl and exploring the role planning plays: A shanghai case study”. Land Use Policy, 67, 426-435.

Travisi C. M., Camagni R. & Nijkamp P. 2010. “Impacts of urban sprawl and commuting: a modelling study for Italy”. Journal of Transport Geography, 18, 382-392.

Thompson, K., & Brown, J. (2006). The effect of service quality and fare levels on ridership of transit services. Transportation Research Part A: Policy and Practice, 40(2), 171-182.

VTA Transit Sustability Policy 2007. “ Bus Rapid Transit service design guideline”.

Wang Y., Wang Z., Li Z., Staley S. R., Moore A. T. & Gao Y. 2012. “A study of Modal Shifts to Bus Rapid Transit in Chinese Cities”. Journal of Transportation Engineering., 133, 515-523.

Wang Y., Wang Z., Li Z., Staley S. R., Moore A. T. & Gao Y. 2012. “A study of Modal Shifts to Bus Rapid Transit in Chinese Cities”. Journal of Transportation Engineering., 133, 515-523.

Williams K, Burton E, Jenks M (Eds), 2000 Achieving Sustainable Urban Form (Spon, London)

Wright, L. 2007. “Bus Rapid Transit planning guide”. Institute for Transportation and Development Policy, New York. USA.

Yao Y. & Wang S. 2014. “Commuting tools and residential location of suburbanization: evidence from Beijing”. Urban, Planning and Transport Research 2, 273-288.

Ye R. & Titheridge H. 2017. “Satisfaction with the commute: the role of travel mode choice, built environment and attitudes”. Transportation Research Part D: Transport and Environment 52, 535-547.

Zahoor, A. et al., 2017. Measuring Urban Sprawl of Srinagar City, Jammu and Kashmir, Indian. Journal of Urban Management. 6, 45-55

Zhao P. 2011. “Car use, commuting and urban form in a rapidly growing city: evidence from Beijing”. Transportation Planning and Technology 34, 509-527.