EXPLORING TRAVEL BEHAVIOR AND MULTIMODAL ACCESSIBILITY IN DHAKA

by

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Candidate's Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedication

"When great trees fall
in forests,
small things recoil into silence,
their senses
eroded beyond fear."

- *Maya Angelou*

People we lost in all these years

who left us with memories and vacuums.

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Abstract

A global paradigm shift from mobility-geared to accessibility-oriented planning is observed in recent years due to the ability of accessibility-oriented planning to integrate land use aspect with transportation planning and consider the 'derived demand' nature of travel. Since accessibility, defined here as the ease of reaching desired destinations, is a measure of potential travel, a large body of studies have been conducted to explore whether it influences actual travel behavior. However, such studies are extremely limited in the context of developing countries and almost non-existent in the context of Bangladesh. The multimodal nature of public transport travel has also received little attention. In this backdrop, the aim of this thesis is to explore and quantify multimodal accessibility and its effects on travel behavior in Dhaka city and synthesize its research and policy implications.

Accessibility has been considered both spatially and temporally in this study. In doing so, the study has considered the data-deprived context of cities of developing countries like Dhaka where traditional methods of incorporating temporal dimension in accessibility analysis is hardly possible. To develop an alternative approach to integrate temporal dimension in accessibility studies, the study has used the simple observation that trip purpose, time-of-day and trip destinations are always interlinked in an urban area. Using spatial autocorrelation approach, the statistically significant destination clusters of Dhaka by peak and off-peak hour were identified. Calculating Modal Accessibility Gap (MAG) showed that the major destinations are highly accessible by car compared to public bus irrespective of any time of the day.

There is a general consensus that socio-economic and demographic, trip, and built environment characteristics influence travel behavior although this influence is far from homogenous. Especially developing countries do not necessarily correspond to evidence found from developed countries particularly when it comes to the effects of built environment characteristics. Binary logistic regression models revealed statistically significant effects of several built environment attributes including accessibility to major destinations on mode choice and household car ownership in Dhaka. This indicates the potential for enhancing public transport accessibility, and future infrastructure investments oriented towards those locations. Alongside that, indications were also found that built environment alone will not be able to bring any drastic change in travel behavior unless mobility-limiting strategies complement accessibility-enhancing strategies and land use planning.

The study findings confirm that accessibility could be a powerful tool to impact travel behavior and there exists a solid basis to evaluate the extent to which accessibility and travel behavior have been meaningfully integrated in the policy and planning documents in Dhaka's context. Reviewing the five most relevant and widely cited policy and planning documents revealed that there exists significant lack of clarity in defining concepts like mobility, accessibility and connectivity. The documents do not explicitly incorporate accessibility and accessibility-related goals and objectives have not been translated to quantifiable measures or performance indicators.

In a nutshell, this research suggests that accessibility is crucial in travel behavior decisions in Dhaka and therefore, can be a fundamental tool in our planning process. A clear conceptualization of accessibility is of huge importance to integrate it in the policymaking and planning process and effectively translate the policies into practice.

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Chapter 1

Introduction

1.1 MOTIVATION AND BACKGROUND OF THE STUDY

The notion of accessibility is one of the most widely discussed yet elusively used concepts in the past few decades. Transportation planning practices have been traditionally shaped by mobility-centered approach which is predominantly based on level-of-service (LOS) measurements. This approach has two major shortcomings. First, it shifts the focus from travel being a derived demand. Second, it ignores the relationship between land use and transportation. Accessibility, on the other hand, considers both land use and transportation. This gives accessibility a substantial edge over mobility since land use-transportation interaction is considered to be an important aspect in sustainable development. Hence, a paradigm shift from mobility-geared to accessibility-driven transportation policy is increasingly gaining importance worldwide due to its far-reaching impacts on urban structure, the performance of transportation systems and various social and economic issues (Cui, Boisjoly, El-Geneidy, & Levinson, 2019; Deboosere & El-Geneidy, 2018; Grengs, 2010; Kawabata, 2003a; Kawabata & Shen, 2006). Yet, considerable challenges exist in this field.

This research is motivated by the observation that there is a significant lack of conceptualization and integration of accessibility and travel behavior in both research and policymaking process, particularly in developing countries like Bangladesh. To understand this observation, two facets need to be recognized. First, since accessibility is a measure of *potential* and is not actual travel behavior, there exists a latent necessity to explore whether potential measures affect realized travel behavior in a particular area (Merlin, 2014). Second, if accessibility has any effect on travel behavior (which many studies suggest), it can be considered as an important tool in policy and planning process of any region.

Dhaka, the capital of Bangladesh is one of the most densely populated cities in the world. Dhaka's transportation sector has received increasing attention in recent years since the city is suffering severely due to rapid urbanization, haphazard development and increasingly worsening public transportation system. Interestingly, accessibility is gradually becoming a buzzword in transportation planning process here. Several policy and planning documents of Bangladesh have recognized accessibility as an important aspect of investment criteria in transportation infrastructure projects and overall urban livability (Dhaka Transport Coordination Board & Ministry of Communications, 2010; Japan International Cooperation Agency & Dhaka Transport Coordination Authority, 2015; Ministry of Communications & Dhaka Transport Coordination Board, 2005; Ministry of Communications & Planning Commission, 2008; Rajdhani Unnayan Katripakkha, n.d.). In spite of that, ironically, accessibility has little received any systematic attention and there exists significant lack of clarity among researchers, practitioners and policymakers in conceptualizing accessibility. As a result, although accessibility has been highlighted in many ways in pen and paper, it could not be translated effectively in the implementation process. First mile/last mile connectivity issue of public transport travel has not received necessary focus as well. Thus, the multimodality of public transport or multimodal accessibility issue is largely ignored in the planning process of the country, as a whole.

Compared to accessibility, there has been relatively more research on travel behavior in Dhaka's context (Ahmed, 2016; Enam & Choudhury, 2011; Habib & Daisy, 2013; Khan, Choudhury, & Wang, 2011). However, none of these studies have attempted to explore the role of accessibility in explaining travel behavior. A large body of studies around the world, nevertheless, have revealed the critical role of accessibility in shaping people's travel behavior (S. L. Handy, 1992; Hanson & Schwab, 1987; Kockelman, 1997; X. Sun, Wilmot, & Kasturi, 1998; Ye & Titheridge, 2017). Whether travel behavior is impacted by accessibility is an unexplored premise in the context of Dhaka. Understanding the extent to which accessibility affects travel behavior requires examining other built environment attributes simultaneously. Given the rapidly changing and intricate nature of urban structure and life here, it is of crucial importance to incorporate these attributes in travel behavior studies.

Summarizing, there exists two-fold issues. Firstly, a lack of systematic study on multimodal accessibility and travel behavior in the context of Dhaka is evident. Secondly, there has been considerable gap in conceptualizing and integrating accessibility and travel behavior issues in research and policymaking process here.

This study aims at filling that gap. In doing so, this study has been attempted to estimate public bus and private car accessibility followed by their effect on travel behavior in Dhaka City. The study also intends to synthesize its research and policy implications in the light of relevant transportation policy and planning documents. Due to time-space constraints associated with public transport and ownership issues associated with private car, these two modes exist at the opposing ends on the common spectrum of travel. The temporal issue is particularly crucial in transportation because people tend to put higher value on time used for travel. As crucial as it is, incorporating temporal dimension is quite challenging, especially in data-deprived context like ours. This study is a take on this aspect as well.

A particular highlight of this research is its take on the interlink of trip purpose, time-of-day and trip destinations in urban area. Since different activity locations often dominantly cluster in different parts of a city, trip destinations and purposes are time-dependent. This has led to the emergence of the concept of *major destinations* in Dhaka (Chapter 4 provides a detailed explanation of this concept). To the author's best knowledge, no systematic study has been conducted so far to portray spatiotemporal variation of car and multimodal public transport accessibility by offering an alternative way of addressing the significant limitations of data on the transit system and spatial opportunities. Additionally, built environment and attitudinal attributes have been largely absent from travel behavior related studies in Bangladesh. Consequently, the role of accessibility on travel behavior in Dhaka has remained unexplored.

In spite of the extensive accessibility-related studies and integration of accessibility-based policies and plans, there is still considerable debate around the world on how to put those theories in practice. Such concerns are even more crucial for developing countries like Bangladesh. Moreover, there has been relatively fewer studies on travel behavior in developing countries compared to developed countries. The current study contributes to the existing literature base in four ways. First, it demonstrates the interlink of trip purpose, time-of-day and trip destinations. Second, it proposes an alternative way of understanding spatiotemporal variation in accessibility even under a semi-structured and mostly unregulated public transport system and data-deprived environment. Although the study concentrates on one city, the context and methodological approach can be applicable to other developing, data-deprived contexts as well. Third, it explores the impact of accessibility in explaining travel behavior in Dhaka. In doing so, the study incorporates a wide array of built environment and attitudinal attributes which will allow a deeper understanding of travel behavior in developing countries. Lastly, it provides a measure for policymakers and urban planners to synthesize theory and practices for efficient, effective and equitable infrastructure investment and management decisions. The approach adopted in this study will allow policymakers to better assess whether the city is actually moving towards accessibility-based planning and pinpoint the areas of potential future investments for equitable distribution of resources and opportunities, particularly in the context of developing countries.

1.2 OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

1. To explore multimodal accessibility to major destinations in Dhaka.
2. To study travel behavior patterns in Dhaka.
3. To integrate research and policy implications of the travel behavior and accessibility patterns identified in the study.

1.3 OUTLINE OF THE THESIS

This research involves a combination of qualitative and quantitative approaches and consists of seven chapters. The present chapter sets the ground for the subsequent chapters by outlining the background and objectives of the research. The second chapter summarizes the concepts and literature in the field of accessibility and travel behavior. Research data, description of the study area and summary of the methodological framework have been presented in the third chapter. The detailed methodologies have been elaborated in the relevant succeeding chapters.

Analytical chapters start with the fourth chapter which addresses the first objective of the research. In this chapter, the statistically significant major destinations of Dhaka by time-of-day have been identified and accessibility to those destinations by public bus and private car have been assessed.

The fifth chapter is dedicated to the second objective. It reports three models to evaluate travel behavior. The third objective has been addressed in the sixth chapter. Prominent transportation policy and planning documents relevant to the study area have been thoroughly studied and research and policy implications of the study have been critically analyzed. This chapter ties the research outcomes from the previous two chapters and integrates that with the policy directions for the city. The last chapter summarizes the study findings, limitations and future research directions.

Chapter 2

Concept and Related Literature

2.1 INTRODUCTION

Two major concepts in this thesis are accessibility and travel behavior. This chapter summarizes the concepts underpinning this thesis and prior related research. In doing so, this chapter sheds light on the paradigm shift from mobility to accessibility in transportation planning and the rich literature base of accessibility and travel behavior related research.

2.2 THE CONCEPT AND MEASURES OF ACCESSIBILITY

"Accessibility... is a slippery notion . . . one of those common terms that everyone uses until faced with the problem of defining and measuring it" (Gould, 1969, p. 64).

The classic yet simplest definition of accessibility probably dates back to 1959 when Hansen (1959) defined it as "the potential for interaction." However simple that might sound, conceptualization and measurement of accessibility, in fact, has been far from simple for urban planners and transportation experts. A more operational definition of accessibility refers to the number of opportunities available within a certain travel time or distance from a given location by a particular transport mode (S. L. Handy, 1992; Kawabata & Takahashi, 2005; Shen, 1998).

Accessibility is a powerful concept because it incorporates the intricate interaction of four components- land use, transportation, temporal and individual (Geurs & Van Wee, 2004). The land use component incorporates the demand and supply, quality of various spatial opportunities and the resulting competition. The transportation component includes not only time, cost and effort associated with trip but also demand and supply of various transport infrastructure. The temporal component highlights availability of opportunities by different times of day and individual's availability of time to take part in relevant activities. The individual component includes various socio-economic, demographic and attitudinal characteristics of individuals (Geurs & Van Wee, 2004).

Accessibility can be measured in a number of ways- each having its own advantages and disadvantages **(Table 2.1)**. Infrastructure-based accessibility measures concentrate on the service and performance of the transportation system and uses travel time and speed, congestion, etc. as evaluation criteria (Ewing, 1993; Geurs & Van Wee, 2004;

Linneker & Spence, 1992). Location-based measures analyze the spatial distribution of opportunities at macro-level (Geurs & Van Wee, 2004). Several such measures have been extensively used (Deboosere & El-Geneidy, 2018; Grengs, 2010; Guy, 1983; Ingram, 1971; Kawabata, 2003a; Vickerman, 1974). The isochronic or cumulative opportunity-based accessibility measure and gravity measure are the most used ones. Cumulative opportunity-based is the simplest and one of the earliest accessibility measures. It counts the number of relevant opportunities available within a certain generalized cost, usually travel time or distance and assumes all opportunities with the predetermined threshold as equally attractive (A. M. El-Geneidy & Levinson, 2006; LaMondia, Blackmar, & Bhat, 2010). Unlike this one, gravity measure imposes a 'friction factor' or impedance function that can take the form of power, Gaussian or logistic function, negative exponential function, etc. (Geurs & Van Wee, 2004; LaMondia et al., 2010). This measure assumes that the farther an opportunity lies in terms of the generalized cost, its attractiveness decreases according to the impedance function (A. M. El-Geneidy & Levinson, 2006). Compared to cumulative opportunity-based accessibility measure, this is more complex and difficult to interpret.

As the name suggests, person-based accessibility measure analyzes accessibility at individual level. It is based on the 'space-time prism' concept of Hägerstrand and considers that an individual's movement is constrained or determined by a space-time budget (Hägerstrand, 1970; Kwan, 1998). This approach is quite robust in nature but complex and data-intensive and therefore, is used less often.

Utility-based accessibility measure is another highly complex, data-intensive and difficult-to-interpret measure. This approach considers travel behavior theories and incorporates individual preferences from a set of potential transport choices (A. M. El-Geneidy & Levinson, 2006; Geurs & Van Wee, 2004; S. L. Handy & Niemeier, 1997; LaMondia et al., 2010).

The extremely crucial role of transport mode in accessibility has been highlighted in several studies. Studies have been conducted on the variation of private automobile and public transport accessibility and led to the development of several concepts like modal mismatch, transport poverty, etc. (Grengs, 2010; Kawabata, 2003a, 2009; Kawabata & Takahashi, 2005; Kwok & Yeh, 2004; Niedzielski & Śleszyński, 2008; Preston & Rajé, 2007). Accessibility has been one of the pivotal arguments in the conceptualization of modal mismatch theory from the original concept of spatial mismatch. Spatial mismatch hypothesis examined the impact of housing-market segregation, crudely defined as geographical distance on employment level (Kain, 1968). While spatial mismatch hypothesis was grounded simply on spatial aspect, several studies found that modal differences, performance of transportation system, land use patterns, etc. play an extremely crucial role in employment level since accessibility to jobs vary significantly depending on travel modes, even more than residential location (Blumenberg & Ong, 2001; Kawabata, 2003a, 2003b; Kawabata & Shen, 2007; Sanchez, 1999). Therefore, accessibility is far more decisive in this regard (Grengs, 2010).

In the past few years, the dynamic nature and temporal variability of public transit accessibility have also been studied (Farber, Morang, & Widener, 2014; Owen & Levinson, 2015). Yet, such studies are more often than not based on developed countries whereas cities of developing countries as well, are increasingly becoming auto-dependent. The multimodality of public transport has received significant attention in recent years unlike earlier studies that used to ignore the walking, waiting and transfer times associated with public transport travel. The emerging capabilities of GIS have made it easier and almost imperative to capture the First Mile/Last Mile issue in contemporary studies (Boarnet, Giuliano, Hou, & Shin, 2017; Farber et al., 2014; Mavoa, Witten, McCreanor, & O'Sullivan, 2012). The term 'multimodality' is used in a number of context and thus, there is not a single definition of it. In this study's context, multimodality means transfer between two or more modes as part of a journey between an origin and a destination (Clifton & Muhs, 2012). Since unlike private automobiles, public transport does not provide door-to-door services and requires feeder modes in completing a journey, it is always multimodal in nature.

While the study of accessibility has been largely focused on public transport and private automobile, walking and bicycling are getting attention in recent years. Studies have found that investment in bicycling infrastructure improve accessibility substantially and is a cost-effective alternative to providing automobile infrastructure (The Accessibility Observatory, 2019; Wu & Levinson, 2019). Although a large body of studies has been primarily dedicated to job accessibility, over time accessibility to various non-work facilities e.g. shopping, health care, public parks, etc. has also been widely studied indicating their important role in urban life (Farber et al., 2014; S. L. Handy, 1992; Hass, 2009; Luo & Wang, 2003; Maat & Konings, 2018). However, developing countries, especially South Asian ones still considerably lack in studies related to accessibility.

Table 2.1: Summary of Accessibility Measures*

Accessibility Measures		Components[a]					Operationalization[b]	Interpretation[b]
		Transport	Land use		Temporal	Individual		
			Demand	Supply				
Infrastructure-based measures		±	–	–	±	–	+	+
Location-based measures	Cumulative opportunities/ Contour measure/ Isochronic measure	±	±	–	±	–	+	+
	Gravity-based measure	+	+	–	±	±	+	±
	Adapted potential measure	+	+	+	±	±	+	±
	Balancing factors	+	+	+	±	±	+	±
Person-based measures		+	+	–	+	+	–	–
Utility-based measures	Logsum benefit measure	+	+	–	–	±	+	±
	Space-time measure	+	+	–	+	+	–	±
	Balancing factor benefit measure	+	+	+	–	±	+	±

[a] Score: + = criterion satisfied; - = not satisfied; ± = partly satisfied [b] Score: + = easy to operationalize/interpret; - = difficult; ± = moderately difficult

*Adapted from Geurs and Van Wee (2004)

2.3 MOBILITY TO ACCESSIBILITY: THE PARADIGM SHIFT

Although the concept of accessibility is not new, it took a long time for urban planners and policymakers to embrace accessibility-based planning instead of the traditional mobility-focused planning. Mobility, defined as 'the ease of movement' and often measured by the traditional level-of-service measures, dominated the 20th century transportation planning and engineering. The notion of accessibility-based planning arose from the widely accepted notion of transportation being a 'derived demand'. Although neither 'sustainable development' nor 'sustainable transportation' emerged during 21st century, the importance of accessibility in planning has taken the major leap with the growing emphasis of 'sustainable development' during this century (Pericles Christopher Zegras, 2005). Yet, for a long time mobility and accessibility have been used interchangeably and enhanced mobility has been thought to be directly resulting into enhanced accessibility. Unfortunately, this ambiguity can still be observed in transportation policies and plans around the world (Boisjoly & El-Geneidy, 2017). Although increased mobility can result in increased accessibility, this is not a simple and universal outcome. People can experience poor accessibility in spite of having good mobility and vice-versa (S. L. Handy, 2002). The traditional mobility-based planning while focuses on better and faster movement, loses the core idea of the need for travel: it becomes pointless to enhance movement unless people can avail the spatial opportunities they want from that movement. Another in-built characteristic of mobility-based planning is to focus primarily on the road network. However, road network does not function in isolation from different land uses. More precisely, unlike other land uses, road network does not have an exclusive function of its own; rather it exists to support the need to reaching different land uses for a variety of purposes. Thus, this seeming separation of land use aspect from transportation aspect in mobility-based approach does not work well in an era of rapid urbanization and industrialization. Accessibility, on the other hand, inherently integrates land use and transportation system and focuses on whether the ease of movement is being translated into the ease of reaching desired opportunities.

Another important aspect of accessibility-based planning is increased choices both in terms of destinations and modes of travel (S. L. Handy, 2002) . Thus, accessibility is directly related to social and environmental equity issues because it allows prioritizing public transit and non-motorized modes which in turn, makes travel easier for poor, women, senior citizens, physically challenged people or simply anyone who do not own or cannot drive a car (A. El-Geneidy et al., 2016; Grengs, 2010; Manaugh, Badami, & El-Geneidy, 2015). Prioritizing public transit and non-motorized modes subsequently reduces congestion and environmental pollution. This is clearly a huge gain over mobility-based approach since no matter how faster movement becomes or how much road space is provided, above a threshold, movement without spatial opportunities will result in growing congestion and consequently slower movement and increased travel times. No wonder sprawl development and mobility-based planning have resulted in almost standstill conditions in cities (S. L. Handy, 2002). Therefore, the ultimate goal of transportation planning should be accessibility with its means being mobility, proximity and connectivity (Grengs, Levine, Shen, & Shen, 2010).

2.4 THE CONCEPT OF TRAVEL BEHAVIOR

The study of travel behavior is undoubtedly one of the most sought after topics by transport planners and researchers. What makes travel behavior so interesting is that human beings, as a whole, are bound to travel in the public realm to survive and thrive. Yet, the 'how' and 'why' an individual travels varies significantly from another individual. Again, an individual's travel behavior may change drastically in the course of life. Even, her daily life does not revolve around a single travel pattern.

People's travel behavior are influenced by the choices they have under certain constraints, their attitudes, societal and cultural norms, and socio-political issues, etc. Again travel behavior influence society, economy and environment. This two-way interaction makes travel behavior an important aspect in policymaking process in any country.

2.5 PRIOR RESEARCH ON TRAVEL BEHAVIOR

Researchers worldwide have taken various approaches to study travel behavior. Some studies are oriented towards individual or household level while others focus on city level travel characteristics. A convenient way to gain an understanding of the existing literature is to summarize them by the travel behavior influencing factors they studied. The factors impacting travel behavior can be broadly categorized into (1) socio-economic and demographic characteristics, (2) built environment/land use characteristics (3) Trip characteristics, and (4) attitudinal characteristics. Here is should be noted that majority of the literatures consider more than one of these characteristics set.

1. Socio-economic and demographic characteristics:

Socio-economic and demographic characteristics at individual and household level have been appeared extensively in travel behavior studies. In majority of the cases, these characteristics play a very important role in influencing travel behavior.

Among the individual and household attributes, age and gender have been found to be important variables though their effect being different across studies. Increasing age has been associated with private vehicle choice possibly due to the inconvenience of walking or using public transit at old age (Kockelman, 1997; Schmöcker, Quddus, Noland, & Bell, 2008; Van den Berg, Arentze, & Timmermans, 2011). The varying effect come from physical and psychological health issues that compel people to give up the pressure of driving and adopt alternative modes (Kim & Ulfarsson, 2004; Truong & Somenahalli, 2015). However, using car as driver and as passenger are not same and the varying effect of age may arise from this fact, at least to some extent (Truong & Somenahalli, 2015; Van den Berg et al., 2011). There is also the effect of gender as older men are more likely to drive compared to older women (Schmöcker et al., 2008; Van den Berg et al., 2011). Interestingly, mobile phone ownership has been found to be associated with public transit use due to better access to public transit schedules (Truong & Somenahalli, 2015).

There have been differing effects of gender on travel behavior possibly due to differences in socio-cultural norms to a large extent. Some research showed increasing likelihood of using a car by women than men while others have found the opposite (Robert Cervero, 2002; Etminani-Ghasrodashti & Ardeshiri, 2016; Ma, Liu, & Chai, 2015; Shen, Chen, & Pan, 2016). Women generally make more complex trip chains than men due to a wide range of household, childcare and social responsibilities and this is again related to women using cars more due to greater flexibility and ease in carrying out chained trips (Ahmed, 2016; McGuckin & Murakami, 1999). The multifaceted activities that women have to perform also has an effect on trip frequency as they tend to make higher than average trips (Srinivasan & Rogers, 2005).

Income is another dominant factor in travel behavior especially in vehicle ownership and mode choice. Higher household income is unsurprisingly associated with increasing vehicle ownership (Kockelman, 1997; Maltha, Kroesen, Van Wee, & van Daalen, 2017; Oakil, Manting, & Nijland, 2016). Household income is also positively associated with higher vehicle and person miles traveled and car mode choice (Akar & Guldmann, 2012;

Blumenberg & Pierce, 2012; Kockelman, 1997). Income influences trip frequency as well- with higher income trip frequency reduces because high income households place higher value on time than low income ones (Srinivasan & Rogers, 2005).

Household composition affects travel behavior e.g. car ownership is influenced by having school-going children in the family (Chu, 2002; Dissanayake & Morikawa, 2002; Li, Walker, Srinivasan, & Anderson, 2010). Interestingly, number of children in the household has been found to be positively associated with number of non-work trips but negatively associated with number of work trips (Etminani-Ghasrodashti & Ardeshiri, 2016). This may result from parents' desire to leave the car for children's school trips instead of work trips and lack of convenient trip chaining option. However, a decreasing disposable family income arising from higher number of children in the household can also have negative effect on car ownership (Gómez-Gélvez & Obando, 2013; P Christopher Zegras, 2010). This indicates that disposable income instead of actual income may be a better predictor of car ownership decisions although this information is harder to obtain than the actual income data (Whelan, 2007). Not only in terms of household demographic characteristics, but also household members' individual trip characteristics play a role in household vehicle ownership decisions and trip chaining patterns, particularly in developing countries with strong family ties (Dissanayake & Morikawa, 2002).

In general, having full-time or professional jobs or jobs with flexible schedule and high educational status are associated with car ownership and mode choice (Kockelman, 1997; Li et al., 2010; Shen et al., 2016). Similar thing is observed for individuals having driver's license (Ewing, Schroeer, & Greene, 2004; Shen et al., 2016). Moreover, race and ethnicity have been considered in some studies though these variables are highly contextual (Ellwood, 1986; Kockelman, 1997).

2. Built environment/land use characteristics:

An extensive amount of literature has been carried out so far to explore the effects of built environment or urban form characteristics on travel behavior. Whereas individual and household attributes of trip-makers are to a large extent beyond the direct influence of urban planners, built environment or land use characteristics, on the other hand, can be planned or altered to a greater degree. Therefore, urban planners and researchers are continuously trying to understand how built environment attributes can be planned or altered to encourage sustainable travel behavior.

The theoretical notion of travel being a 'derived demand' states that people do not travel for pleasure (although this aspect is being challenged by many researchers these days, it is not within the scope of our current study), rather they travel to reach places that serve their particular needs. Thus, it is assumed that the attributes of those places will directly and indirectly affect how and why people travel. The wave of new urbanism and resulting concepts like compact development, transit-oriented development (TOD), etc. are predominantly based on this conception.

That built environment influences travel behavior is a generally accepted idea today. The challenge, however, is that the effect varies considerably across space. We outlined in the earlier sub-section that socio-economic and demographic characteristics may have varied effect on travel demand. Research suggests that the degree of variation of built environment effects is way greater than socio-economic and demographic characteristics. This poses a dilemma for urban planners and policymakers: they potentially have greater influence on something that have a highly diversified outcome.

A classic nomenclature of the wide range of built environment variables was put forward for the first time in 1997 and known as the 'Three Ds" or "D Variables": Density, Diversity and Design (Robert Cervero & Kockelman, 1997) . The density variable can be expressed in a number of ways including population, employment, dwelling units, retail floor space, etc. and can be measured as gross or net density. The diversity measure indicates the degree of land use mix in an area. The two most common diversity variables are entropy and dissimilarity index, both ranging from values of 0 to 1 where 0 indicates completely homogenous land use and 1 indicates heterogeneous land use. Less common diversity variables include job-housing balance, vertical mixture, activity center mixtures, etc. The design measures stem from street network characteristics and therefore, the resulting layout of an area. Commonly used design variables include proportion of 3-leg and 4-leg intersections, connected node ratio or proportion of non-dead end intersections, street density, sidewalk ratio, bicycle land density, etc.

Where density and diversity is more related to land use pattern, design is related to transportation network characteristics. The concept of "Three Ds" was later expanded to destination accessibility, distance to transit, demand management (e.g. parking demand and supply, etc.) and demographics (Ewing & Cervero, 2010). However, the original concept in 1997 by Cervero and Kockelman also included accessibility under density measures. On the other hand, demographics are more related to socio-demographic characteristics and less related to built environment.

The earlier travel behavior research, though did not completely disregard land use effect on travel behavior, emphasized more on the socio-demographic factors (Hanson, 1982). Generally it is hypothesized that urban form variables e.g. density, mixed land use, accessibility, etc. promotes walking/bicycling and transit use, reduces vehicle ownership and use and trip generation rates by bringing opportunities nearby. Contrary to early research, several studies have confirmed this hypothesis. A study back in 1988 on the USA's 57 largest suburban employment centers confirmed that land use mixing increases more walking, bicycling and ridesharing where single land uses promotes more single occupant vehicle (SOV) uses (R Cervero, 1988). Down that line, a 1994 study in Puget Sound Region found statistically significant relationship between employment density and land use mix with decreasing SOV use and increasing walking and transit use for work trips but interestingly no significant correlation was found between the mode choice variables and land use mix in case of shopping trips (Frank & Pivo, 1994). Some studies also emphasize that density is more influencing in commuting mode choice than land use mix with higher density encouraging walking/bicycling (Robert Cervero, 1996). One of the reasons of the relationship between increasing residential density and decreasing car ownership stem from the increasing public transit level-of-service in high density neighborhoods (Kitamura, Mokhtarian, & Laidet, 1997). However, the effect of mixed land use was found to be differing with different density neighborhoods. One important finding from this study is that it found when a household owns four automobiles, their odds of commuting by transit drops below 6% irrespective of their neighborhood's built environment characteristics. This is crucial because it indicates that beyond certain level of personal and household attributes, land use aspects probably do not exert much influence.

Compared to density and land use mix, use of accessibility indices came at a fairly later stage in travel behavior studies. Accessibility has been found to be a powerful predictor of Vehicle Miles Traveled (VMT), non-work trip distance, car ownership and mode choice and sometimes even more powerful than density and land use mix (S. L. Handy, 1992; Hanson & Schwab, 1987; Kockelman, 1997; X. Sun et al., 1998; Ye & Titheridge, 2017). Transit share have been found to be positively associated with accessibility by transit (Moniruzzaman & Páez, 2012). Accessibility and connectivity have also been found to be important in differentiating captive and choice users' modal split modeling

(Beimborn, Greenwald, & Jin, 2003). Moreover, increasing accessibility to reduce driving has been proposed to be a promising policy option after finding the causal relationship between built environment and travel behavior (S. Handy, Cao, & Mokhtarian, 2005). This also echoed in a study based on Madrid and Barcelona which found that lack of public transport accessibility increased car ownership especially outside the central cities (Matas, Raymond, & Roig, 2009).

Historically speaking, travel behavior and built environment related literature has predominantly been based on developed countries, particularly the USA, for a long period of time. Nevertheless, the impact of land use attributes on travel behavior has been ascertained by several studies on Asian cities. Population and job density have been found to be negatively associated and increasing parking supply to be positively associated with commuting by driving in Hong Kong (Zhang, 2004). By presenting a base model and an expanded model, it was found that for both Boston and Hong Kong, inclusion of land use variables significantly improved the mode choice models indicating the powerful role of urban form metrics.

Location appears be a crucial factor for low-income population. A study on two Indian settlements reveal that residents of peripheral location spend more time and money for work commutes compared to more centrally located residents. Due to accessibility to more central city opportunities, the centrally located population tend to make more walk and bicycle trips while the residents of peripheral location make more bus trips. They also make higher than average trips due to accessibility to various non-work opportunities (Srinivasan & Rogers, 2005).

Land use mix as measured by entropy and dissimilarity index were found to significantly influence mode choice in the Indian city of Rajkot (Munshi, 2016). Commute distance was found to be a good predictor of walk mode choice but had little effect on bicycle and auto rickshaw modes in this study.

Sidewalk coverage on street network and fewer dead-end roads have been found to be influencing walk trips to school (Ewing et al., 2004; Schlossberg, Greene, Phillips, Johnson, & Parker, 2006). Suburban street network or increased 3-leg intersection showed evidence of increased car use (P Christopher Zegras, 2010). Higher transit stop density and reduced distance to nearest transit station makes it easier to navigate the public transport system and therefore, increases the likelihood of transit travel including disabled and older people (Kitamura et al., 1997; Schmöcker et al., 2008). A joint analysis on Washington Metropolitan Area found direct and indirect effect of built environment on driving mode choice but also emphasized the importance of considering car ownership as a mediating variable in the choice modeling (Ding, Wang, Tang, Mishra, & Liu, 2018).

The significant impact of neo-traditional neighborhood on mode choice and trip frequency demonstrated itself in a quasi-experimental North Carolina based study on two neighborhoods- one conventional and another neo-traditional. The study found that the neo-traditional households generated 8.6% fewer total trips and traveled 24.3% fewer miles per day than the conventional neighborhood. Moreover, households in neo-traditional neighborhood made more walking and bus trips and fewer car trips than the conventional neighborhood (Khattak & Rodriguez, 2005).

Contrary to general hypothesis, many built environment variables have been found to be showing opposite effects. No conclusive evidence could be put forward on the effects of local and regional accessibility and neo-traditional neighborhood on non-work travel in San Francisco Bay Area (S. L. Handy, 1992). Nevertheless, this research pointed towards the necessity of considering the neighboring area characteristics or regional accessibility in evaluating the effect of neo-traditional neighborhood on travel behavior.

Again, residential density, land use mix and accessibility has been found to be exerting little effect on household trip generation rate (Ewing, DeAnna, & Li, 1996). In Santiago, Chile, population density has been found to be negatively associated with number of walk trips (P Christopher Zegras, 2004). Density had very little effect on walk, bicycle and auto rickshaw mode choice Rajkot as well (Munshi, 2016). Accessibility and distance to school showed negative influence on bus mode choice in terms of school trips indicating that school bus chosen only when parents themselves cannot drive children to school due to very long trip length (Ewing et al., 2004; Schlossberg et al., 2006). Including interaction effects of built environment measures in auto speed, non-work activities and vehicles miles traveled (VMT) models also indicate that creating a pedestrian and transit-friendly network alone will bring little change in travel behavior unless intervention measures are geared towards reducing auto-speed (Chatman, 2008). Contrary to North American context, living further from urban center has been found to be negatively associated with car ownership in Beijing and Chengdu, possibly resulting from the tendency of wealthy, car owning households to live close to urban center to avail good facilities (Li et al., 2010). A similar finding came from another

Chinese city Shanghai where higher job density was found to be related with increasing driving (B. Sun, Ermagun, & Dan, 2017).

In a study based on an Iranian metropolitan city Shiraz, street density and connectivity have been found to be encouraging car use in non-work trips due to increased road supply and internal connectivity for drivers (Etminani-Ghasrodashti & Ardeshiri, 2016). This is contrary to some previous studies (Frank & Engelke, 2005; B. Sun et al., 2017; Vance & Hedel, 2007). A reduction in non-motorized commuting trips with increased land use mix was also observed in this study.

An interesting analysis came from a study on Japanese metropolitan city Kyoto-Osaka-Kobe and the southern California coast in the USA which estimated that the effect of accessibility differ based on the extent of motorization in an area: accessibility does not have any effect when the city reaches a matured level of motorization (Kitamura, Akiyama, Yamamoto, & Golob, 2001). This notion, however, needs more evidence to be established which the authors also mentioned. Matured level of motorization in California which demonstrated itself with 99% of the households having at least one car and nearly half of the households having two cars, such automobile dependency would bring the entire city at a standstill point sooner or later, leaving little room for accessibility.

One point can be extracted from some of the literature discussed above: many of the deviations from our general hypotheses have been observed in Non-North American cities. Thus, the importance of more research on travel behavior in developing countries cannot be emphasized more.

The residential self-selection bias in travel behavior is not extensively studied. Nevertheless, the few studies conducted so far indicate that residential self-selection is possibly a very crucial determinant in travel behavior. A 2009 study based on 38 empirical research based on mostly North American and few European data provide strong indication of weakening effect of built environment on travel behavior after residential self-selection is accounted for (Cao, Mokhtarian, & Handy, 2009). Controlling for residential self-selection, a recent meta-regression analysis of 37 studies conducted between 1997 and 2013 found that compact development appear to be little influential in reducing driving and land use mix may even induce more driving, which may perhaps result from the introduction of new facilities that would not have been made if those facilities were not located in that area (Stevens, 2017). In developing country as well tendency of residential self-selection was found (Munshi, 2016). These studies suggest the importance of considering residential self-selection in travel behavior research.

3. Trip characteristics:

Effect of trip characteristics on travel behavior is generally consistent. Increasing commuting distance is associated with increasing vehicle ownership and use and reduced walking/bicycling (Robert Cervero, 1996; Munshi, 2016; B. Sun et al., 2017; Van den Berg et al., 2011). Also trip purposes influences mode choice decisions: having daily necessities e.g. grocery or medical store within 30 feet distance from home reduces the likelihood of transit use because car is a more convenient option for such trips (Robert Cervero, 1996). Travel time and fare have been found to statistically significant predictors in mode choice in Boston and Hong Kong (Zhang, 2004). This raised the importance of effective pricing policies in reducing automobile dependency.

4. Attitudinal characteristics:

The importance of attitudinal characteristics in assessing travel behavior has received attention fairly recently compared to other attributes discussed so far. The first few among the noteworthy literature that addressed this attribute considered 39 attitudinal statements in studying travel behavior in San Francisco Bay Area (Kitamura et al., 1997). They concluded that attitudes play a more important role than socio-economic and neighborhood characteristics in explaining travel behavior and emphasized that changes in urban form characteristics will bring little change in altering travel behavior unless attitudinal changes are brought. Down that line, it was found that attitudes vary among conventional and neo-traditional neighborhood residents indicating that there exists self-selection issues in travel behavior (Khattak & Rodriguez, 2005). Attitudes regarding transport network convenience, safety, comfort, etc. have been found to influence car ownership decisions (Li et al., 2010; Shen et al., 2016).

2.6 CONCLUSION

The summary of the existing literature base suggests that there has been limited research on multimodal accessibility and travel behavior in the context of developing countries, even more in the context of South Asian ones. Moreover, there is significant gap in integrating related research, policy and practice. A take on this insight is that there is substantial need in understanding the accessibility and travel behavior scenario in the context of developing South Asian countries, Furthermore, it is crucial to integrate the research findings with policy implications. These could be considered good reasons to devote efforts in drawing a comprehensive sketch of multimodal accessibility and travel behavior in the context of Dhaka and thereby synthesize the research and policy implications in this thesis.

Chapter 3

Research Design

3.1 INTRODUCTION

Based on the background and objectives presented in the first chapter, this chapter provides an outline of the research design. First, the study area context has been presented. Next, the data sources and methodological framework have been illustrated.

3.2 STUDY CONTEXT

The study area includes 90 Traffic Analysis Zones (TAZs) of Dhaka City Corporation area as demarcated in Dhaka Urban Transport Studies (DHUTS), 2010. The TAZ boundaries coincide with the ward boundaries of the city enabling easy use of various socio-economic and demographic data required for this study.

Dhaka is one of the world's most densely populated city, and the hub of majority of the commercial and administrative activities of the country (Demographia, 2019). Moreover, the city has experienced rapid growth in educational, recreational, etc. facilities over the years. Over the years, rapid urbanization and population influx have posed significant challenges in providing adequate and quality services in every sector here. A brief overview of the demographic and economic characteristics of the study area is given below **(Table 3.1).**

Table 3.1: Demographic and Economic Characteristics of the Study Area

Area (sq. km.)	126.34
No. of Households	1,576,746
Population	6,970,105
Female	3,093,519
Male	3,876,586
Population Density (per sq. km.)	55,169
Literacy Rate (7 years and above) (%)	74.6
Employment Status of Population (15 years and above) (%)	
Employed	57.0
Looking for Job	0.93
Household Work	22.8
Do not Work	19.0

(Bangladesh Bureau of Statistics, 2014)

The land use characteristics of Dhaka shows that residential land use dominate among all. The proportion of mixed land use is noticeable as well. Nearly 13% of the land belong to transportation and communication **(Table 3.2).**

Table 3.2: Land Use Characteristics of the Study Area

Land Use	**% Area**	**Land Use**	**% Area**
Residential	41.98	Community Facilities	1.39
Commercial	4.57	Administrative	1.00
Mixed Use	9.71	Agriculture	0.32
Education and Research	3.68	Transport and Communication	12.97
Industrial	1.95	Water Body	8.48
Health Facilities	0.63	Open Space	2.67
Institutional	1.98	Restricted and Vacant Land	8.66

(Detailed Area Plan GIS database, 2019)

Dhaka's transportation sector has received increasing attention in recent years. The city is burdened with severe and increasingly worsening traffic congestion. Along with high population density, deteriorating public transportation system and increasing private car ownership and use are said to be primarily responsible for this status quo. Out of all newly registered cars in 2018 in Bangladesh, nearly 90% has been registered only in Dhaka. The number is increasing steadily- in 2011, 11,423 cars were newly registered and by the first three months of 2019, 3,627 private cars have been newly registered (Bangladesh Road Transport Authority, 2019, April 8). On the other hand, although the modal share of public bus is nearly six times higher than car, the bus system is still semi-structured without any specific schedule and regulation (Rajdhani Unnayan Katripakkha, n.d.). The bus routes with substantial overlapping mostly expand in the north-south direction and lack connectivity in the east-west direction **(Figure 3.1)**. This poses massive challenges since the public transportation can hardly provide reliable service and reasonable coverage.

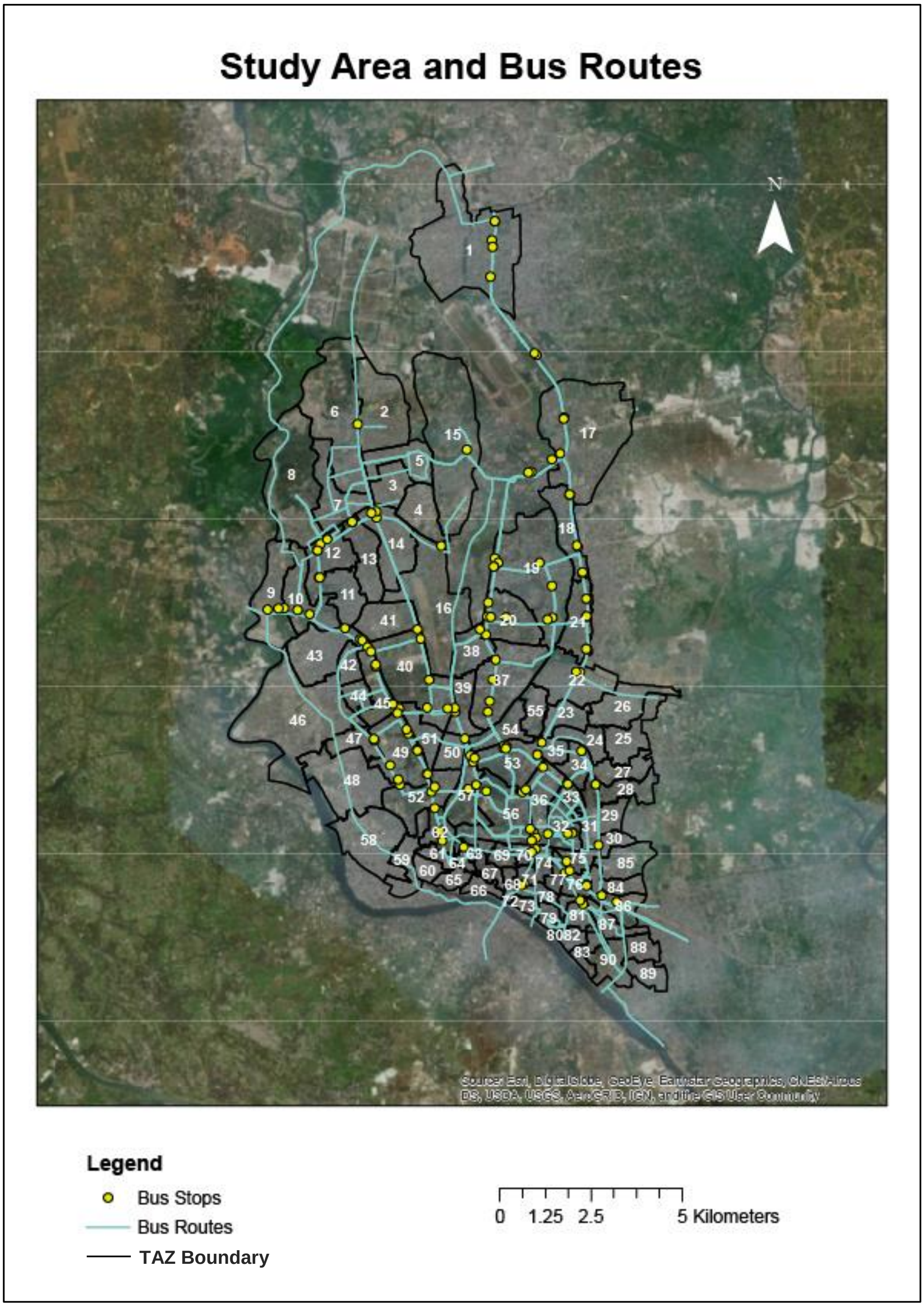

Figure 3.1: Study area and bus routes (numbers denote TAZ no.)
(Source: DTCA, 2015 and Field Survey, 2018; Satellite Image Source: ESRI)

3.3 OVERVIEW OF DATA AND METHODOLOGY

This section provides a quick outline of the data and methodology used in the research. This research adopts a combination of qualitative and quantitative methods including extensive use of several spatial and statistical analysis tools. Each analytical chapter is dedicated to one of the objectives outlined in the Chapter 1. Since every chapter takes a unique method to fulfill the respective objective, the detailed methodological framework has been outlined in each chapter.

3.3.1 Data Sources

The analysis relies on bus route and street network data, bus stop locations, average speed of car and bus during commuting and non-commuting hours, DHUTS 2010 Household Interview Survey (HIS) data, TAZ-wise economic opportunities data, and land use data in Dhaka city. Bus route and DHUTS, 2010 HIS data have been collected from Dhaka Transport Coordination Authority (DTCA). The HIS database contains an array of socio-economic, demographic and trip data on more than 13,000 households covering detail information on all the trips made by all the household members on one regular working day. The trip database had information including trip origin, destination, purpose, travel time, travel distance etc. TAZ-level employment data were collected from Bangladesh Bureau of Statistics (BBS) and land use data were collected from Rajdhani Unnayan Katripakkha (RAJUK). Bus stoppage locations as updated by Dhaka Metropolitan Police (DMP) in 2018 were collected through a GPS survey. Average journey speed data of car and bus during peak and off-peak hours for different functional categories of streets were derived from field survey for every working day of a week in 2019. Average waiting time for bus was collected through a household questionnaire survey conducted in 2017. Due to unavailability of waiting time data at the new bus stoppages, the data collected for old bus stoppages were used. The street network and structure data were obtained from OpenStreetMap (OSM) to create network datasets. OSM data have the default geographic coordinate system of WGS 1984. To align with other GIS data, this data were projected to Bangladesh Transverse Mercator (BTM) projected coordinate system in ArcGIS.

3.3.2 Methodological Framework

The analytical chapters start with Chapter 4 which extensively uses Geographic Information System (GIS) to assess accessibility to major destinations by multimodal public bus and private car. By our definition, the major destinations are the clusters that attract a considerably high number of trips and are simultaneously spatial and temporal entity. The major destinations have been identified using spatial autocorrelation approach in GeoDa. Accessibility has been calculated using a cumulative opportunity-based metric. This chapter demonstrates the linkage among trip purpose, time-of-day and trip destinations and provides an understanding on modal accessibility gap and modal mismatch scenario from both spatial and temporal perspective.

Chapter 5 concentrates on travel behavior. In particular, it focuses on understanding the impact of accessibility on mode choice and car ownership in Dhaka. At first, it provides a general overview of travel behavior scenario using descriptive statistics. Discrete choice binary logistic regression model has been used to develop mode choice and car ownership models. A wide array of individual and household characteristics, built environment, and attitudinal characteristics have been used in modeling purpose. This wide range of variables allow to capture the effect of accessibility on mode choice and car ownership decisions.

In Chapter 6, qualitative approach has been taken to review the key transportation policy and planning documents. By using a mixed content-structuring analysis (also known as 'keyword in context'), this chapter has tried to assess the extent to which multimodal accessibility and travel behavior have been meaningfully incorporated in the selected policy and planning documents.

Chapter 4

Spatial and Temporal Multimodal Accessibility in Dhaka City

4.1 INTRODUCTION

The first research theme this thesis attempts to examine is multimodal accessibility scenario in the context of Dhaka. Public transport is getting renewed interest around the world as an essential means of sustainable urban development. Public transport does not provide door-to-door services and therefore, inherently multimodal in nature. In this study, multimodality is defined as transfer between two or more modes as part of a journey between an origin and a destination (Clifton & Muhs, 2012). Compared to unimodal trips, multimodal public transit trips always involve certain disadvantages in terms of ingress and egress time, waiting time, fixed routes and schedules, etc. (Lei & Church, 2010; Mavoa et al., 2012). Thus, public transport accessibility always falls short of unimodal accessibility or more precisely, private car accessibility, which provides door-to-door services.

Examining the existing condition of multimodal accessibility is of increasing importance to improve public transport accessibility and reduce private automobile dependency. However, simply examining multimodal accessibility, albeit necessary, is not sufficient to come up with any effective policy implications. Although both private car and public bus serve the need of travelling to avail desired activities and services, time-space constraints associated with public transport and ownership issues associated with private car create substantial difference on the services these two modes offer and people's attitude towards them. In an era of increasing disposable income, ownership of private automobile as a symbol of social status, industrialization, urbanization and sprawl development, it is crucial to understand the existing car accessibility in a city as well. Moreover, in spite of the growing automobile ownership as highlighted in the previous chapter, a large segment of the population still depend on public transport and will continue doing so. Against 28.5% of the trips made by public bus, only 5.2% trips have been made by private car in Dhaka (Japan International Cooperation Agency, 2010). This underscores the importance of public transport in developing countries like Bangladesh. The comparative overview of public transport and private car accessibility could, in fact, better pinpoint the areas of concern and caveats in the overall transportation system and help in reducing automobile dependency.

Comparing public transport and private car accessibility side-by-side is not new (Grengs, 2010; Kawabata, 2003, 2009; Kawabata & Takahashi, 2005; Kwok & Yeh, 2004; Niedzielski & Śleszyński, 2008). Yet, such studies are more often than not based on developed countries whereas cities of developing countries are rapidly becoming auto-dependent. Developing countries still lack in studies related to the variation of multimodal public transport accessibility and private car accessibility. Furthermore, the lack of data in developing countries adds significant barrier in conducting such studies.

In this backdrop, this chapter will focus on analyzing car and multimodal public bus accessibility from spatial and temporal dimension in Dhaka. Accessibility analysis, in this study, is grounded on a simple understanding that trip purpose, time-of-day, and trip destinations are always intertwined in an urban area. Therefore, accessibility analysis should adequately incorporate this matter for effective policy implications. In this research, the data-deprived environment of the study area has been considered. It is common in developed countries to use General Transit Feed Specification (GTFS) data to estimate accessibility. However, Dhaka's public transport is semi-structured with no specific schedule system. Therefore, there exists no specific public transport time-table and GTFS data. Incorporating temporal dimension in accessibility analysis, therefore, requires identifying some alternative methods other than the conventional ones like using GTFS database, etc. Thus, this study attempts to find an alternative method of incorporating temporal dimension in such settings.

The approach of this research is to assess multimodal public bus accessibility by comparing car accessibility side-by-side. In this study, walking has been chosen as the feeder mode of public bus. Henceforth, *multimodal accessibility* and *walk-bus accessibility* will be used synonymously in this study.

4.2 THE CONCEPT OF MAJOR DESTINATIONS

Studies on origin-based accessibility often measure accessibility of a location by considering all reachable opportunities. Whereas the approach of considering all reachable opportunities is a good point to start, it may be insufficient or even misleading when it comes to policy implications. This is especially true when employment opportunities are considered as the generalized 'relevant opportunities' in accessibility estimation, which is a widely accepted norm for ease of definition, calculation and more importantly, absence of reliable, complete data of other spatial opportunities. For example, people tend to make more non-work trips during the off-peak period compared to work trips. Therefore, a person residing near the central business district may have high accessibility in the conventional sense, but that may be of little significance for her during off-peak hours. Rather an individual living close to shopping areas may enjoy advantages over her during off-peak periods.

Added to that, in an urban area, different activity locations often dominantly cluster in different parts of the city. Mandatory and discretionary activities do not necessarily cluster in the very same locations. Therefore, while commuting hours are expected to attract traffic at certain locations, non-commuting hours would not automatically attract traffic in those same locations. This understanding is crucial especially from policy standpoint.

The problem with the conventional approach of measuring accessibility is that it could potentially overestimate or underestimate accessibility by focusing more on theory instead of what a person could and would realistically expect to achieve in her everyday life. More precisely, it ignores the fact that trip purpose, time-of-day and trip destinations are always interlinked in an urban area and cannot be isolated from one another. Another shortcoming of existing studies is that although they focus on the temporal variation of public transit accessibility, they barely look into the temporal variation of car accessibility. However, car accessibility as well can vary significantly due to traffic congestion.

This study is an attempt to address the interlink of trip purpose, time-of-day and trip destinations, leading to a more reliable illustration of what opportunities a city-dweller would realistically expect to avail in different times of the day by private car and multimodal public transport. To the author’s best knowledge, no systematic study has been conducted so far to portray spatiotemporal variation of car and multimodal public transport accessibility by offering an alternative way of addressing the significant limitations of data on the transit system and spatial opportunities. Compared to the conventional approach, the approach in this study, would allow policymakers to better assess whether the city is actually moving towards accessibility-based planning and pinpoint the areas of potential future investments for equitable distribution of resources and opportunities, particularly in the context of developing countries.

Putting in simple terms, the notion of major destinations refer to the TAZs attracting a significant number of total trips by different times of the day. Here, it is assumed that the TAZ clusters attracting a high number of trips are the activity hubs of the city. Dhaka being the capital of a country that is continuously trying to bring major breakthroughs in economic, infrastructure, and communication sectors in recent years, this approach of identifying major destinations is particularly important from the policy perspective. This approach would allow to isolate the potential locations where transportation and infrastructure investments need to be prioritized. Therefore, it is vital to understand the existing accessibility to these major destinations.

4.3 METHODOLOGY

4.3.1 Statistically Significant Major Destinations Estimation

Since trip attraction would potentially be different for the TAZs for different times of the day based on their land use and socio-demographic characteristics, etc., the major destinations have been identified considering temporal dimension. The attracted trips across TAZs were aggregated for the peak and off-peak hours. Morning and evening peak hours refer to 8:00–10:30 am and 4:30–7:00 pm respectively (Nippon Koei Co. Ltd, 2015). The off-peak hour is not clearly defined for Dhaka city. Different studies have found low traffic flow variability across the day and sometimes identified all time periods other than the peak hours as off-peak hour (Japan International Cooperation Agency & Dhaka Transport Coordination Authority, 2015; Nippon Koei Co. Ltd, 2015). Considering this context, 6:00-7:00 am, 12:00-3:00 pm and 7:30-9:00 pm have been jointly chosen as off-peak hours to adequately represent a wide array of potential non-work trips including social, recreation, shopping, etc. as well as homeward trips presumably because that often involves discretionary activities without a rigid time period (like work or school trips). From DHUTS HIS database, it was found that more than two-thirds of the total trips are attracted within these time windows, thereby, giving sufficient ground to identify our major destination clusters considering these time periods.

Next, the number of attracted trips by TAZs during the peak and off-peak hours was extracted. This trip attraction data across the TAZs were used to estimate the statistically significant major destinations. Applying first order queen contiguity in GeoDa, Univariate Local Moran's I was then performed at $p<0.05$ to estimate statistically significant destination clusters by time-of-day.

The local Moran for a spatial unit i was calculated using **Equation 1** (Anselin, 1995).

$$I_i = (z_i / m_2) \sum_j w_{ij} z_j \qquad (1)$$

Here, z_i, z_j are deviations from the mean and the summation over j is based on neighboring values where $j \in J_i$. w_{ij} are non-zero spatial weights when i and j are neighbors. Conventionally, $w_{ii} = 0$. In queen contiguity, neighbors include spatial units having shared vertices or shared edges (Anselin, 2018).

The Local Indicator of Spatial Autocorrelation (LISA) cluster maps were generated in this process. The LISA map and Moran Scatter Plot offer classification of spatial association into four categories relative to the mean. The mean is the center of the scatter plot and the categories are defined by the location of the points in the four quadrants on the graph (Anselin, 2019). The high-high clusters indicate high values surrounded by other high values. The low-low clusters indicate low values surrounded by other low values. The high-low clusters indicate high values surrounded by other low values. The low-high clusters indicate low values surrounded by other high values.

The high-high clusters in these maps are the points of interest here because they indicate high trip attracting TAZs surrounded by other high trip attracting TAZs. Unlike spatial outliers, the LISA cluster maps show only the core of the spatial clusters. The actual clusters include the neighbors of the cores (Anselin, 2019). This method was employed to determine statistically significant, namely major destination clusters **(Figure 4.1).** Here, it is to be noted that an individual TAZ might attract a high number of trips but unless it is also surrounded by other high trip attracting TAZs, it would not be a major destination according to this methodology.

4.3.2 Network Dataset Creation and Travel Time Estimation

Two network datasets were prepared in ArcGIS- one for car and the other one for multimodal network including walk and bus. Bus route data collected from DTCA showed that there are 226 bus routes in Dhaka totaling in 194.87 km. In preparing the network datasets, average car and bus speeds during peak and off-peak hours were applied which were derived from field survey for every working day of a week for different functional categories of streets. A walking speed of 4.8 km/hour was assumed for the multimodal network dataset (Farber et al., 2014). The bus stoppages were used as transfer points for switching between transport modes. Since public transit travel involves waiting time at transit stations as well as boarding and alighting delays, they should be added to the in-vehicle travel time (IVTT) to adequately reflect the actual scenario. Average waiting time at bus stoppages of 7.5 minutes derived from the field survey was added in the multimodal network dataset. Since no boarding and alighting time data was available for Dhaka, a total boarding and alighting delay of one minute was assumed.

Spatial representation of TAZs and structures for the network analysis were generated by their centroids snapped to the nearest street features. Once the network datasets were prepared, travel times between the centroids of the structures and destination TAZs during peak and off-peak hours were estimated using the O-D Cost Matrix Solver in ArcGIS. Each individual structure was used as the origin and statistically significant major destination TAZs within the city limits as destinations in the OD cost matrix analysis. The Network Analyst OD Cost Matrix Solver tool in ArcGIS uses Dijkstra's algorithm to find the optimum path through the network in terms of the chosen impedance. In this study, the impedance is the total travel time between an origin-destination pair. The algorithm does not impose any limitation on pedestrian walking time (Farber et al., 2014). Therefore, the resultant matrix may include 'walk- only' routes if that optimizes the travel time compared to bus.

Using three cut-off travel times of 30, 45 and 60 minutes, this procedure was performed twice- once for car and walk-bus each. Average travel times for work and non-work trips in the study area have been found to be around 53 minutes and 48 minutes respectively (for different non-work purposes the average travel time ranges from 32 minutes to 54 minutes). Considering all trips, average travel time is 57 minutes. Therefore, these three cut-off travel times of 30, 45 and 60 minutes seem reasonable for accessibility estimation in the study's context.

4.3.3 Accessibility Calculation with Consideration of Spatial Unit

Effects of Spatial Unit in Accessibility Analysis

The spatial unit of measuring accessibility has crucial impact on the precision of results. Researchers have to deal with aggregation errors in spatial accessibility analysis. Such aggregation errors arise from considering a single point (often the centroid) as the representative of an entire aerial unit of spatially distributed individuals or opportunities (Hewko, Smoyer-Tomic, & Hodgson, 2002). Therefore, choosing large spatial units produce generalized estimation of accessibility i.e. same accessibility score within a TAZ or census tract, etc. Such generalizations might be misleading- in real world, for instance, all parts of a TAZ or census tract are hardly at the same distance from a transit stop or a destination or have exactly the same street characteristics.

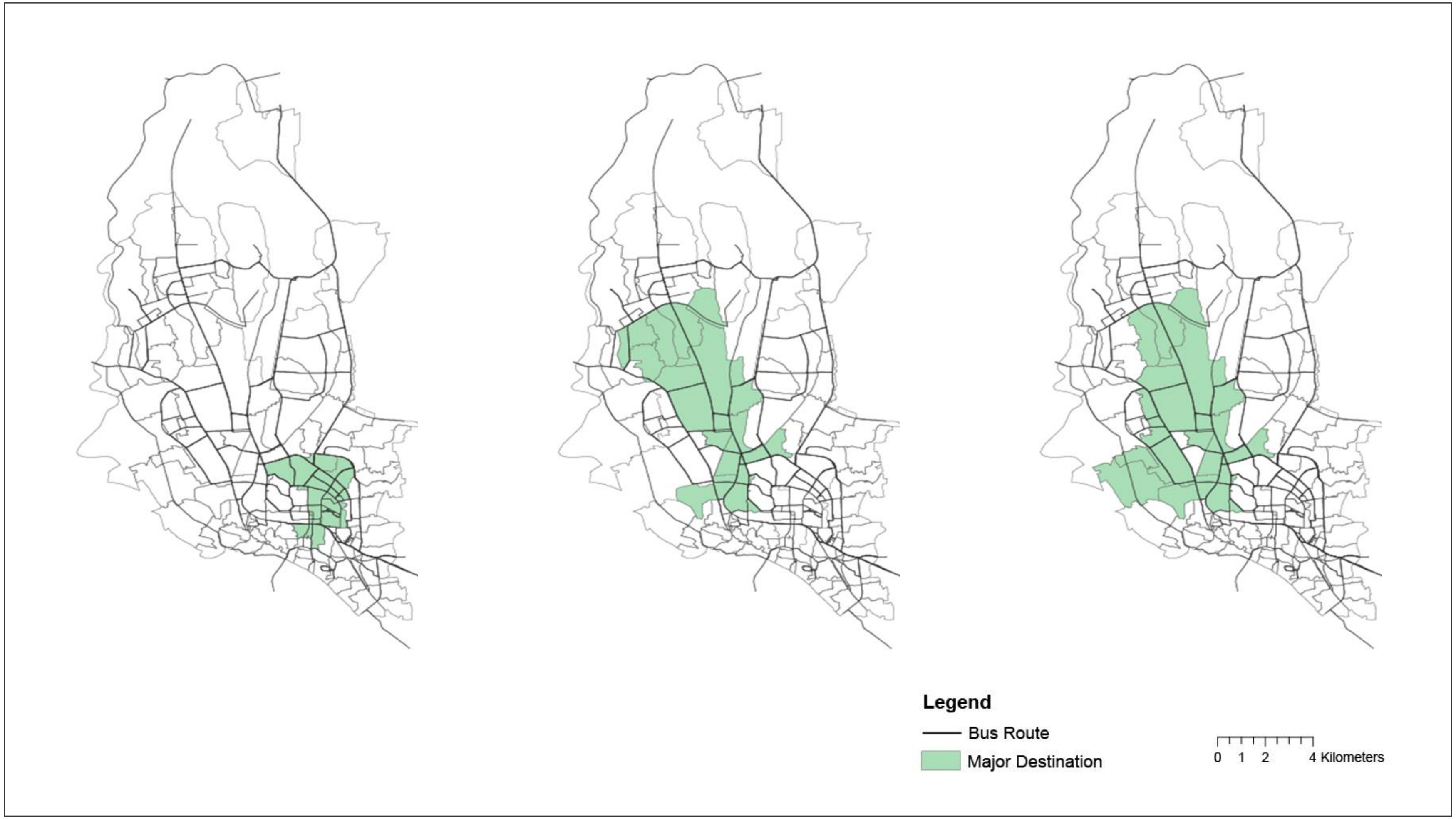

Figure 4.1: Statistically significant major destinations by time-of-day (from left to right: morning peak, off-peak and evening peak)

This is even more vital when accessibility is estimated through a multimodal street network involving public transit and walking/bicycling because the total travel time by public transit includes a considerable amount of walking, waiting and transfer time along with the in-vehicle travel time. The "First Mile/Last Mile" (FMLM) connectivity issue significantly alters accessibility estimation at an aggregate level. Since the more spatially disaggregated the data are, the less prone it is to aggregation error, choosing the finest resolution unit is often a desirable and widely used method to deal with aggregation errors (Hewko et al., 2002).

Considering this, finer grained spatially disaggregated data has been used for this study. Instead of considering zone centroids as origins, accessibility was measured at individual structure level which is the smallest possible unit for location based accessibility measures in the context of Dhaka. Spatial distribution of the structures in the study area varies considerably across TAZs **(Figure 4.2)**. TAZs in the southern part have denser distribution of structures compared to other parts, particularly the central part of Dhaka. There are 260,762 structures in total with an average of nearly 2,897 structures per TAZ. TAZ 73 has the least number of structures- 310 and TAZ 1 has the highest- 11,132.

Accessibility Calculation

Since there is no actual data of number of available employment opportunities for Dhaka city, Total Persons Engaged (TPE) across TAZs was used as a proxy variable for job opportunities available assuming no vacancy exists. TPE varies noticeably across TAZs and does not depend on the area of the TAZs **(Figure 4.3)**. Some larger TAZs have comparatively lower TPEs while some smaller ones have higher number of TPEs. TAZs in the southern part and some in the central part have higher TPEs than other parts. The mean TPE is approximately 24,635. TAZ 32 and 33 have the highest and least number of TPEs which are 86,477 and 2,516 respectively.

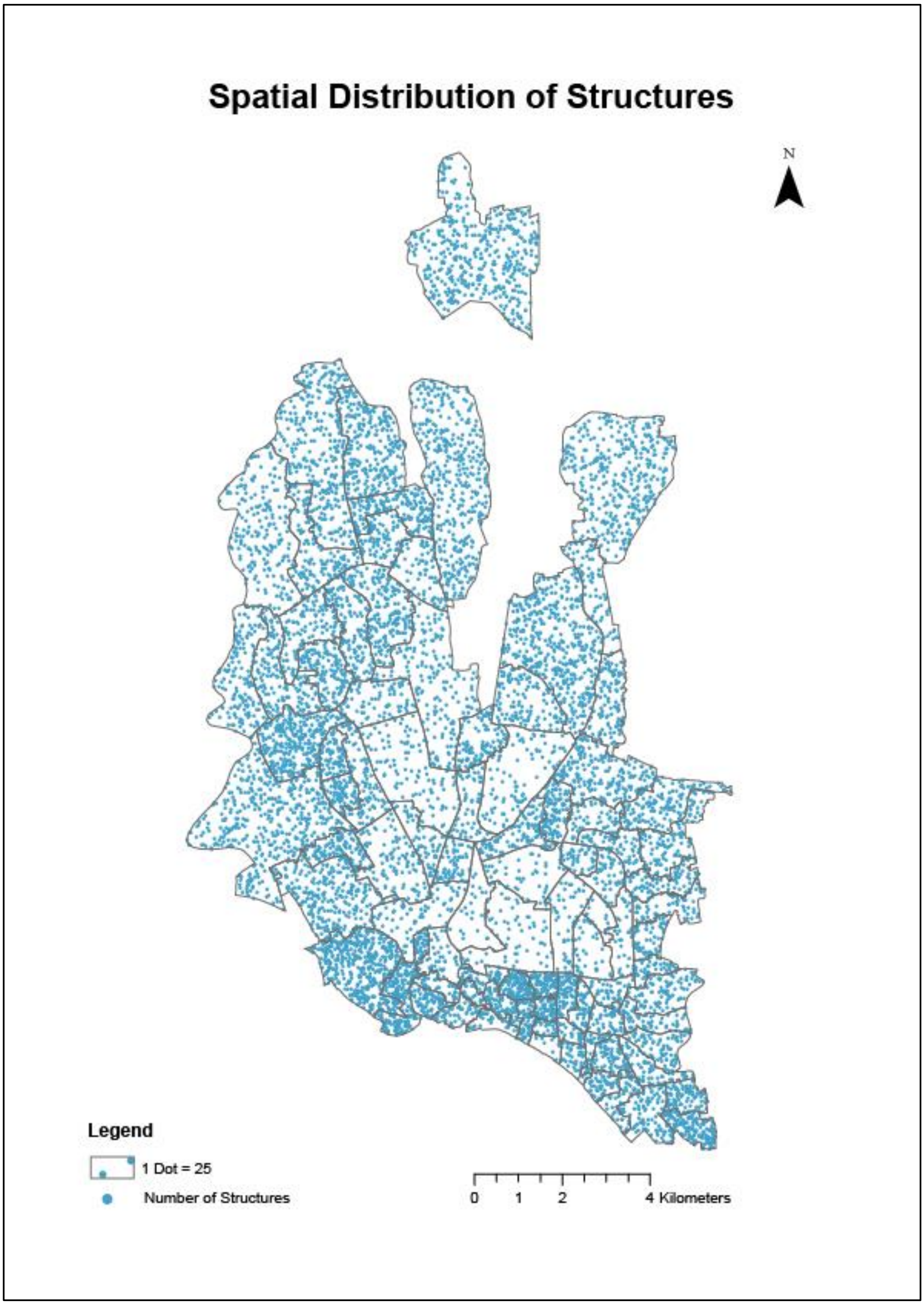

Figure 4.2: Spatial distribution of structures in the study area

Figure 4.3: Spatial distribution of employment opportunities in the study area

Using the origin-based cumulative-opportunity accessibility metric mentioned in **Equation 2**, public bus and car accessibility scores for all individual structures within the study area were calculated (Shen, 1998). Since the focus is on integrating theory and practice in this research, an accessibility metric has been chosen which is the easiest to interpret and communicate and requires the least amount of data.

$$A_i = \sum_j O_j f(C_{ij}) \qquad (2)$$

where

A_i = accessibility for structure i
O_j = number of employment opportunities in destination TAZ j
C_{ij} = travel time for a trip from i to j
$f(C_{ij})$ = impedance function measuring the spatial separation between i and j

The structure level accessibility scores were then aggregated by averaging across each TAZ to generate a TAZ level accessibility score. The TAZ level accessibility scores allow easier visualization and understanding of accessibility scenario at the city scale and enables synthesis of other TAZ level socio-economic, demographic and travel data. Yet, accessibility scores were calculated at a more disaggregate level first and then aggregated because it would reduce some likely aggregation errors arising from calculating accessibility directly at a larger spatial scale as discussed in the previous sub-section (Apparicio, Abdelmajid, Riva, & Shearmur, 2008).

One challenge of working with highly disaggregated spatial data is the rigorous computational requirements. It is inconvenient and sometimes impossible to do that using traditional spreadsheet software functions and capabilities because it requires huge amount of time and splitting of datasets into several smaller parts. To deal with this challenge, R statistical programming language was used to analyze the large datasets efficiently (R Core Team, 2018).

4.3.4 Modal Accessibility Gap (MAG) Calculation

Simple ratio of car-bus accessibility at the TAZ level is the easiest and simplest way to calculate accessibility gap. However, it can produce unusually large values, which are difficult to represent, compare and interpret. Therefore, Modal Accessibility Gap (MAG) between car and walk-bus was calculated using **Equation 3** (Kwok & Yeh, 2004).

$$MAG = \frac{A_c - A_p}{A_c + A_p} \qquad (3)$$

A_p and A_c are population-weighted zonal accessibility index for public bus and car respectively where,

$$A_p = \sum_{i=1} \frac{M_i}{M} A_i^p$$

$$A_c = \sum_{i=1} \frac{M_i}{M} A_i^c$$

M_i is the total population in TAZ i and M is the total population in the whole city.

This standardized index ranges from -1 to 1, thereby allowing a very easy and quick comparison. An extreme 1 indicates outright advantage of car over public transport and vice-versa when the value is -1. MAG is 0 when accessibility by car and bus are equal. On the other hand, when a TAZ has no accessibility by both the modes, the index cannot be computed mathematically and conceptually as well, there exists no 'gap' in actual sense. This standardized index has another advantage over the simple ratio approach because it allows measuring gap when a TAZ has no accessibility by one of the modes. In such cases, the simple ratio approach would produce misleading result: based on the denominator and numerator, the ratio would either be 0 or infinite. Thus, the MAG index is particularly suitable for this context because quite some TAZs have car accessibility but no multimodal accessibility.

4.4 RESULTS AND DISCUSSION

4.4.1 Time-of-day and Statistically Significant Major Destinations

The identification of statistically significant major destinations by different times of the day come from the simple observation that distribution of trip purposes vary by time of day and in an urban area different activity locations may dominantly cluster in different parts of the city. Peak hour trips often involve work and school trips and non-work or discretionary activities can expand all day round, especially taking place during off-peak and evening peak hours. Thus, different parts of the city may attract different proportion of trips based on peak and off-peak hours. The percentage of trips attracted by purposes and different times of day (since the attempt is to find the statistically significant major destinations, attracted trips are more of interest here than generated trips) clearly shows that the distribution of trip purposes are not uniform all day long and expectedly so **(Table 4.1)**. In addition, isolating self-employment work trips from work trips in general shows that a noticeable percentage of off and evening peak trips consist of such trips, possibly due to greater flexibility in work schedule.

Table 4.1: Purpose of Trips by Time-of-day

Trip Purpose		**Morning Peak**	**Off-peak**	**Evening Peak**
Homeward		2.49%	18.25%	14.65%
Work		27.17%	2.22%	0.68%
Work (Self-employment)		9.83%	26.61%	17.68%
School		19.53%	3.80%	0.37%
Non-work	Shopping	5.61%	3.98%	18.77%
	Social	4.57%	4.35%	8.64%
	Recreation	1.50%	1.92%	6.76%
	Religious	0.41%	0.60%	0.77%
	Medical	3.42%	2.15%	5.08%
	Others	25.48%	36.12%	26.60%
	Non-work Total	40.99%	49.12%	66.62%
Total		100.00%	100.00%	100.00%

(Calculated from DHUTS, 2010 trip database)

The statistically significant major destinations by time-of-day confirms that morning peak hour trips, off-peak hour trips and evening peak hour trips mostly cluster in different locations within the city **(Figure 4.1)**. The statistically significant major destination cluster for morning peak hour includes parts of Motijheel, Ramna and Old Dhaka that contain the commercial hub of the city as well as several big schools and colleges. This seems to represent morning peak hour well since a high proportion of work and school trips are made then. The off-peak hour cluster involves a mix of TAZs: TAZs with residential characteristics like Kalabagan, Mirpur, Ramna as well as market areas like New Market and commercial-industrial area like Tejgaon. These areas also consist of several schools and day-shift of the schools contribute to the off-peak school trips. Given the mix of trip purposes during the off-peak hour, such a cluster seems consistent. The homeward and non-work trips dominate the evening peak hour. Therefore, residential areas like Mohammadpur, Mirpur, Dhanmondi (Dhanmondi also hosts a wide array of non-work activity locations like shopping malls, restaurants and food courts, etc.) and shopping areas like New Market seem to adequately define the evening peak major destination cluster. Here it is to be emphasized that the major destinations are simultaneously spatial and temporal entity and they should not be thought separately without either of the dimensions.

Therefore, it could be reasonably said that accessibility analysis should adequately incorporate the understanding that trip purpose, time-of-day and trip destinations are always interlinked in an urban area and cannot be thought in separation from one another.

4.4.2 Overview of Spatial and Temporal Variation in Car and Multimodal Accessibility to Major Destinations

Accessibility zones are mostly clustered and accessibility decreases outward direction from the major destination clusters **(Figure 4.4)**. Difference in accessibility by walk-bus and car is staggering **(Table 4.2)**. Travelling 30 minutes by car would take 51.43% of the population to at least some of the major destinations irrespective of time of day. An hour of travel by car would substantially increase this number- 97.37% of the population would be able to reach at least some of the major destinations. On the contrary, a striking 9.8% of the population could never reach to any major destination within 60 minutes of travel by walk-bus.

Less than 1% (0.87%) of the population could attain at least moderate accessibility level (morning peak, 60 minutes) by walk-bus. On the other hand, more than half of the population (54.59%) could attain at least moderate accessibility level with 60 minutes travel by car.

The maps depict that for some TAZs, changes in accessibility level from one cut-off travel time to the next is more drastic for car than bus. An increase in 15 minutes travel time strikingly improve car accessibility for some TAZs. However, even doubling the travel time brings very little or no change in accessibility level for bus users in some TAZs. This pattern is noticeable in both peak and off-peak periods.

To confirm this observation, it was tested whether changes in accessibility levels from one cut-off travel time to the next is statistically significantly higher for car compared to bus. Since the data has non-normal distribution because of several TAZs having zero accessibility at lower cut-off travel time and by walk-bus, a non-parametric sign test was performed. It was found that except for accessibility changes from 45 minutes to 60 minutes, the change from one cut-off travel time to the next is statistically significantly higher for car than bus for all other cases (p=0.034 for 30 minutes to 45 minutes cut-off travel time and p=0.000 for the remaining ones).

On an average, travelling 30 minutes by car would make at least 13% of the jobs in the major destinations reachable irrespective of time-of-day. An hour of travel by car would substantially increase this number- at least 55.08% of the jobs would be accessible within that time. On the contrary, at most only 12.84% of the jobs could be reached within 60 minutes of travel by walk-bus. That is even lower than the jobs available within 30 minutes of travel by car.

Poor bus accessibility is particularly noticeable during morning peak **(Figure 4.4 (a-c))**. Although this is the only time period when at least a TAZ attain moderate accessibility, nearly half of the population still have no accessibility to the major destinations within 60 minutes bus travel **(Table 4.2)**. Showing an opposite scenario, a 60 minutes travel by car would yield high accessibility to more than half of the population during that very time of the day. Interestingly, though bus accessibility does not improve beyond low accessibility level in any other time period, they have comparatively fewer population at no accessibility level by 60 minutes travel (18.56% and 19.33% during off-peak and evening peak respectively) **(Table 4.2)**.

Accessibility does not reach to 'very high' level during morning peak for any mode. Because accessibility scores were standardized across all time periods, a relatively smaller cluster of statistically significant major destinations compared to off and evening peak seem to be responsible for this.

Table 4.2: Percentage of Population and Number of TAZs under Different Accessibility Levels *(Standardized accessibility scores)*

Time of Day	Travel Time	Mode	No Accessibility *(0.00)*		Very Low *(0.00-0.20)*		Low *(0.20-0.40)*		Moderate *(0.40-0.60)*		High *(0.60-0.80)*		Very High *(0.80-1.00)*	
			% Pop	TAZ	% Pop	TAZ	% Pop	TAZ	% Pop	TAZ	% Pop	TAZ	% Pop	TAZ
Morning Peak	30 minutes	Walk-Bus	75.98	55	23.42	34	0.6	1	0.00	0	0.00	0	0.00	0
		Car	34.19	19	19.10	15	10.46	7	19.64	23	16.61	26	0.00	0
	45 minutes	Walk-Bus	59.13	38	38.38	48	2.49	4	0.00	0	0.00	0	0.00	0
		Car	16.13	9	23.26	13	3.25	3	19.64	20	37.72	45	0.00	0
	60 minutes	Walk-Bus	48.15	30	45.10	51	5.88	8	0.87	1	0.00	0	0.00	0
		Car	2.63	1	20.08	11	9.41	6	15.44	15	52.45	57	0.00	0
Off Peak	30 minutes	Walk-Bus	46.64	50	53.36	40	0.00	0	0.00	0	0.00	0	0.00	0
		Car	6.33	6	22.22	19	45.32	45	24.09	19	2.04	1	0.00	0
	45 minutes	Walk-Bus	26.40	31	66.45	55	7.15	4	0.00	0	0.00	0	0.00	0
		Car	0.00	0	7.88	5	11.19	14	40.11	41	30.77	21	10.04	9
	60 minutes	Walk-Bus	18.56	20	65.54	57	15.91	13	0.00	0	0.00	0	0.00	0
		Car	0.00	0	2.63	1	2.43	3	14.37	18	29.22	26	51.35	42
Evening Peak	30 minutes	Walk-Bus	39.39	45	60.61	45	0.00	0	0.00	0	0.00	0	0.00	0
		Car	19.82	22	43.99	38	34.20	28	1.99	2	0.00	0	0.00	0
	45 minutes	Walk-Bus	29.79	34	66.49	53	3.72	3	0.00	0	0.00	0	0.00	0
		Car	6.33	6	21.04	18	33.75	30	31.09	28	7.78	8	0.00	0
	60 minutes	Walk-Bus	19.33	18	65.30	59	15.37	13	0.00	0	0.00	0	0.00	0
		Car	2.63	1	5.25	4	19.27	16	28.65	29	31.89	29	12.31	11

Table 4.3: Percentage of Jobs Reachable by Car and Walk-Bus at Different Cut-off Travel Time

Time-of-day	Travel Time (minutes)	Mode	% Reachable Jobs
Morning Peak	30	Walk-Bus	4.84
		Car	53.28
	45	Walk-Bus	9.13
		Car	70.21
	60	Walk-Bus	12.84
		Car	81.19
Off-peak	30	Walk-Bus	2.34
		Car	30.15
	45	Walk-Bus	4.89
		Car	58.29
	60	Walk-Bus	9.21
		Car	80.29
Evening Peak	30	Walk-Bus	2.22
		Car	13.00
	45	Walk-Bus	4.68
		Car	32.96
	60	Walk-Bus	8.41
		Car	55.08

Car accessibility shows a somewhat bleak picture during evening peak at 30 minutes cut-off time, most possibly due to a relatively lower journey speed. More TAZs and therefore, a larger population achieves some accessibility by bus during off-peak than morning peak. Looking at the spread out cluster of accessibility zones around the major destinations, it could be said that this might be largely due to a bigger cluster of statistically significant major destinations during this time-of-day, leading to more available opportunities to a bigger segment of the population.

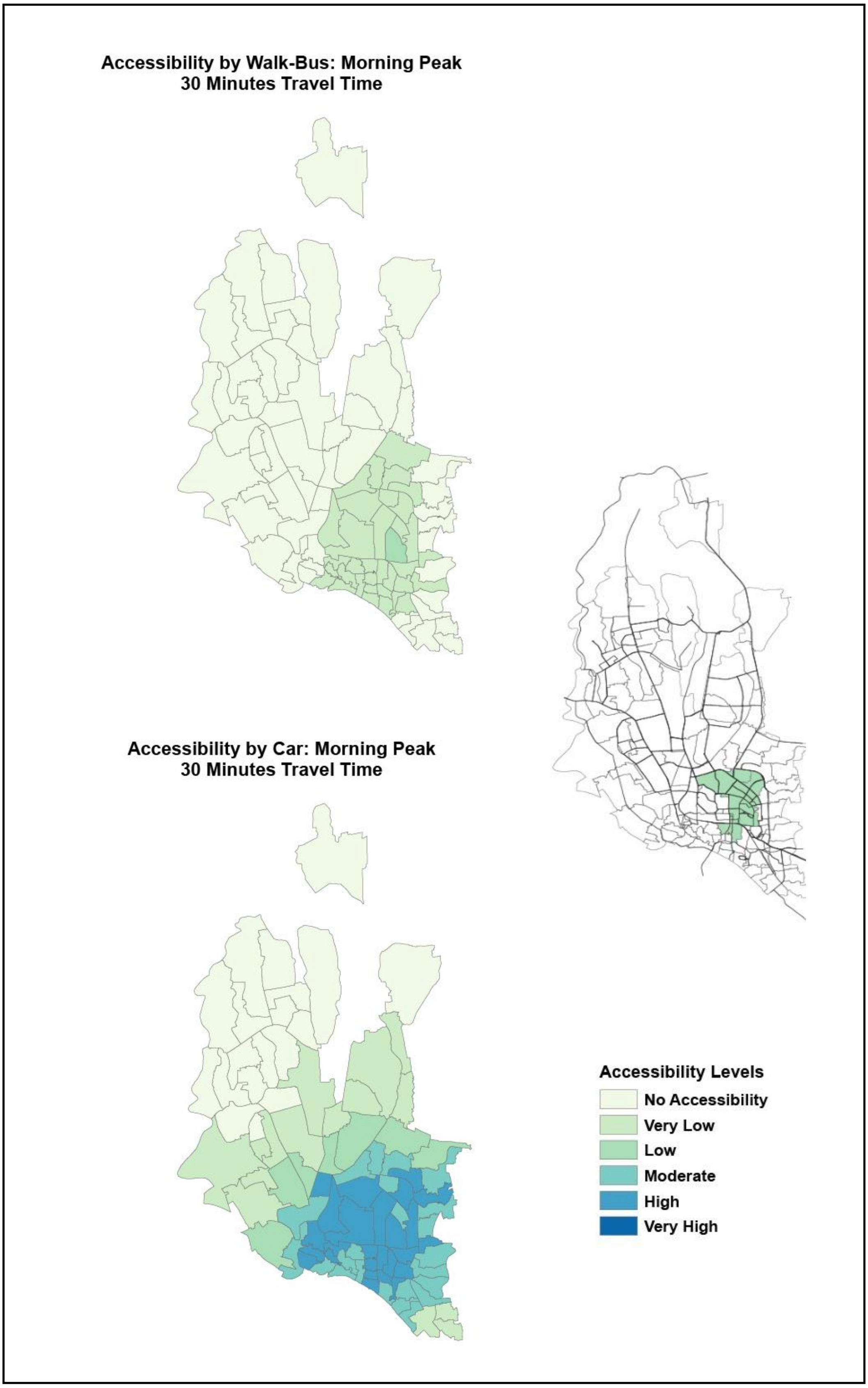

Figure 4.4 (a): Morning peak accessibility at 30 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during morning peak)

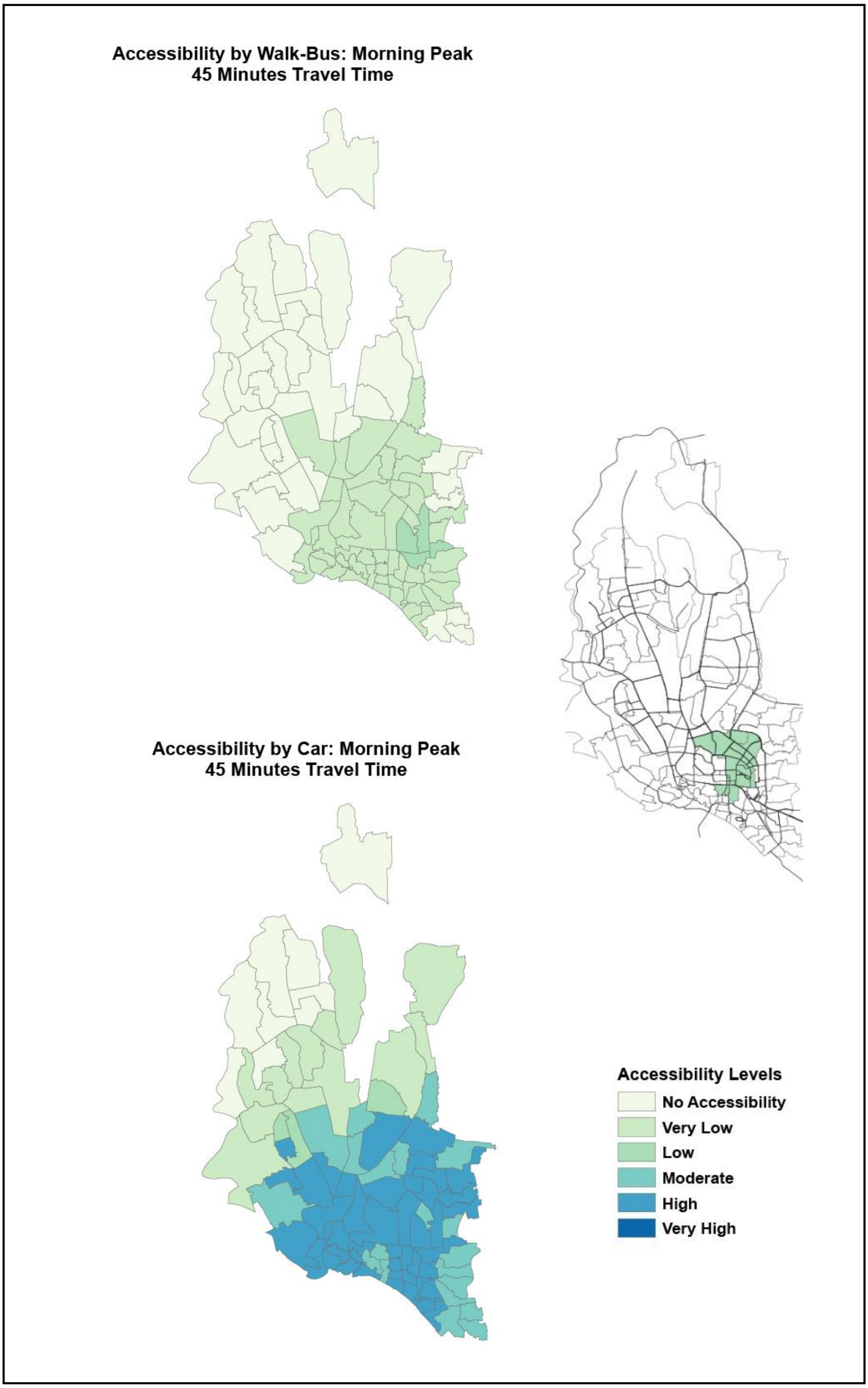

Figure 4.4 (b): Morning peak accessibility at 45 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during morning peak)

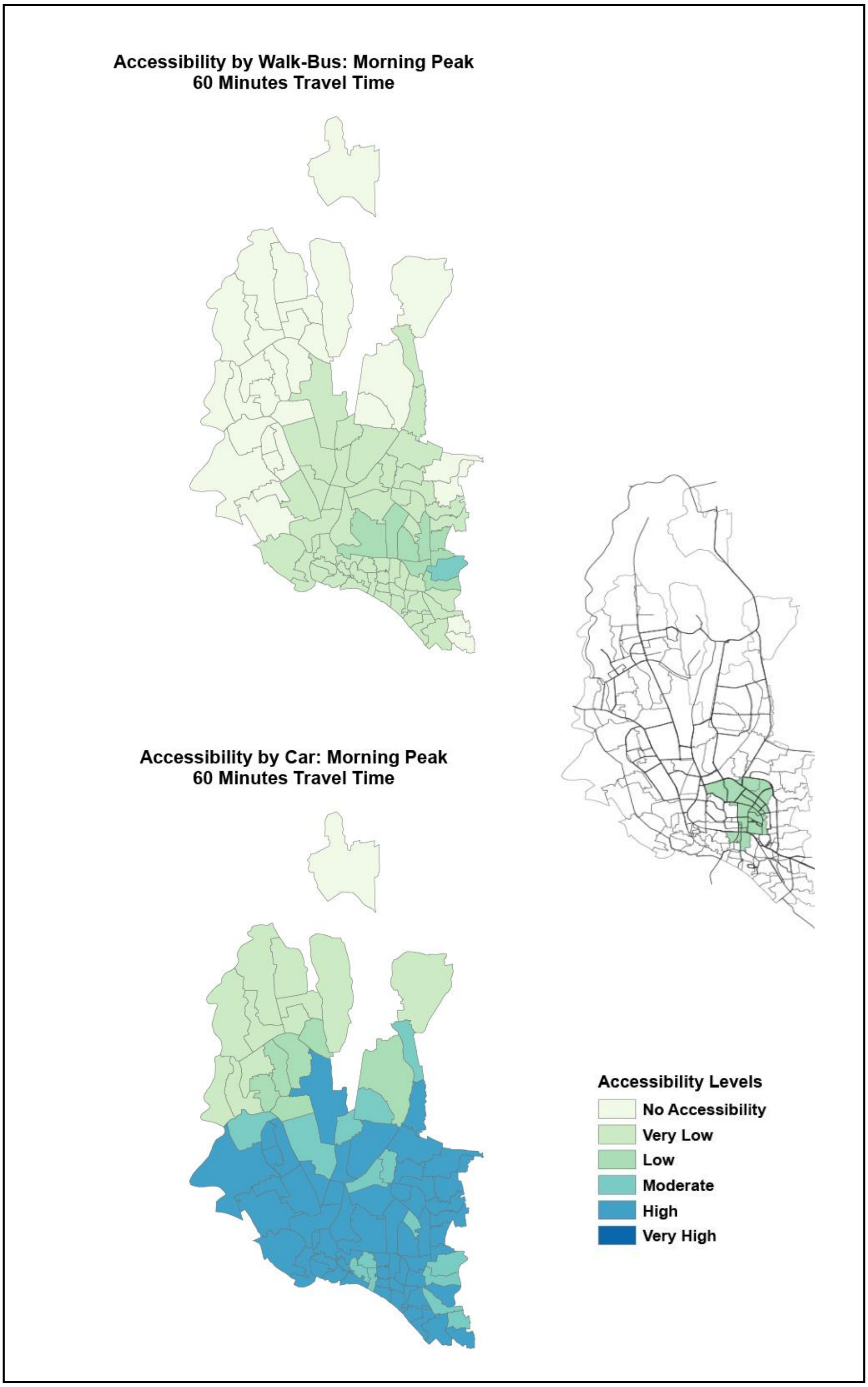

Figure 4.4 (c): Morning peak accessibility at 60 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during morning peak)

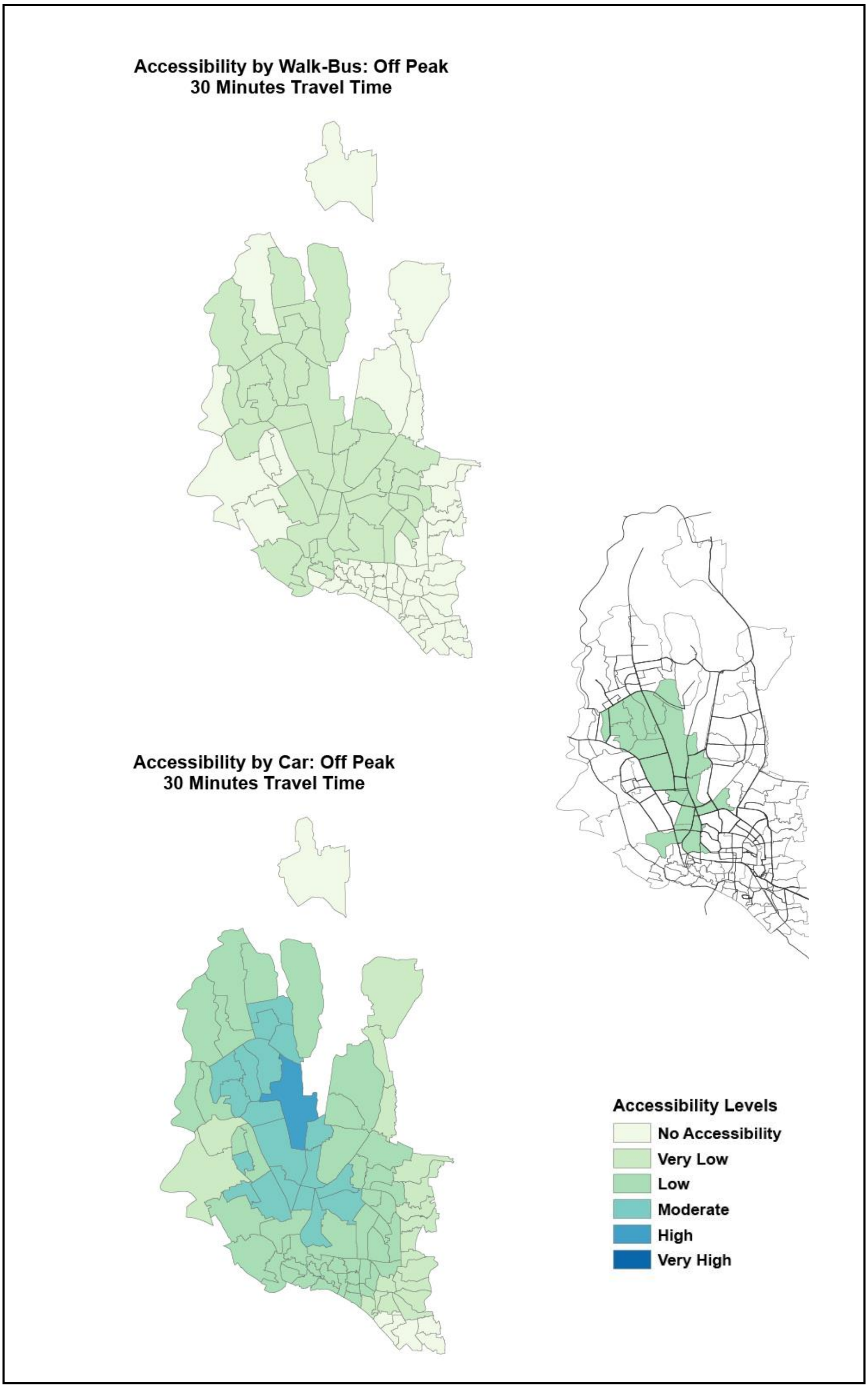

Figure 4.4 (d): Off peak accessibility at 30 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during off peak)

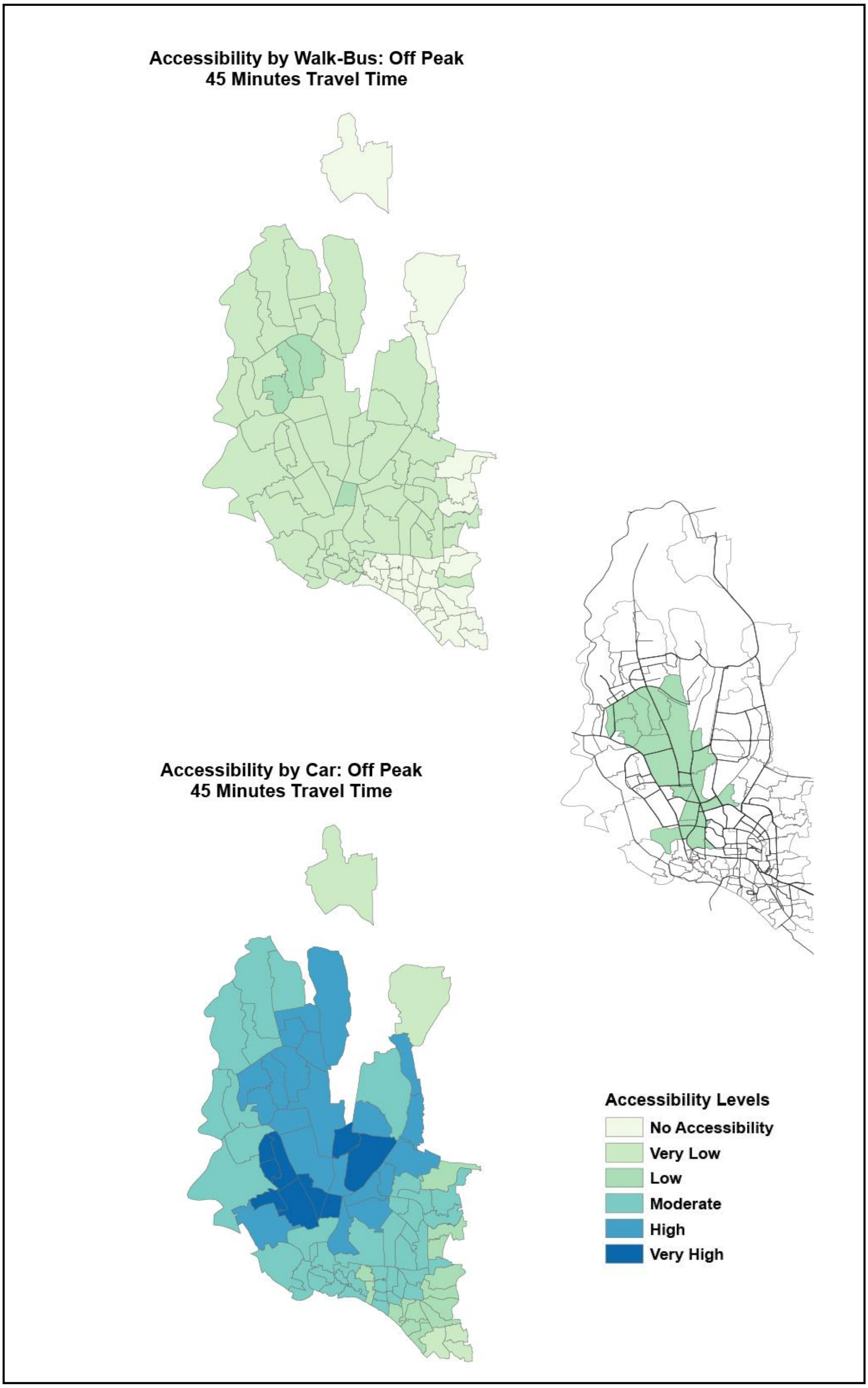

Figure 4.4 (e): Off peak accessibility at 45 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during off peak)

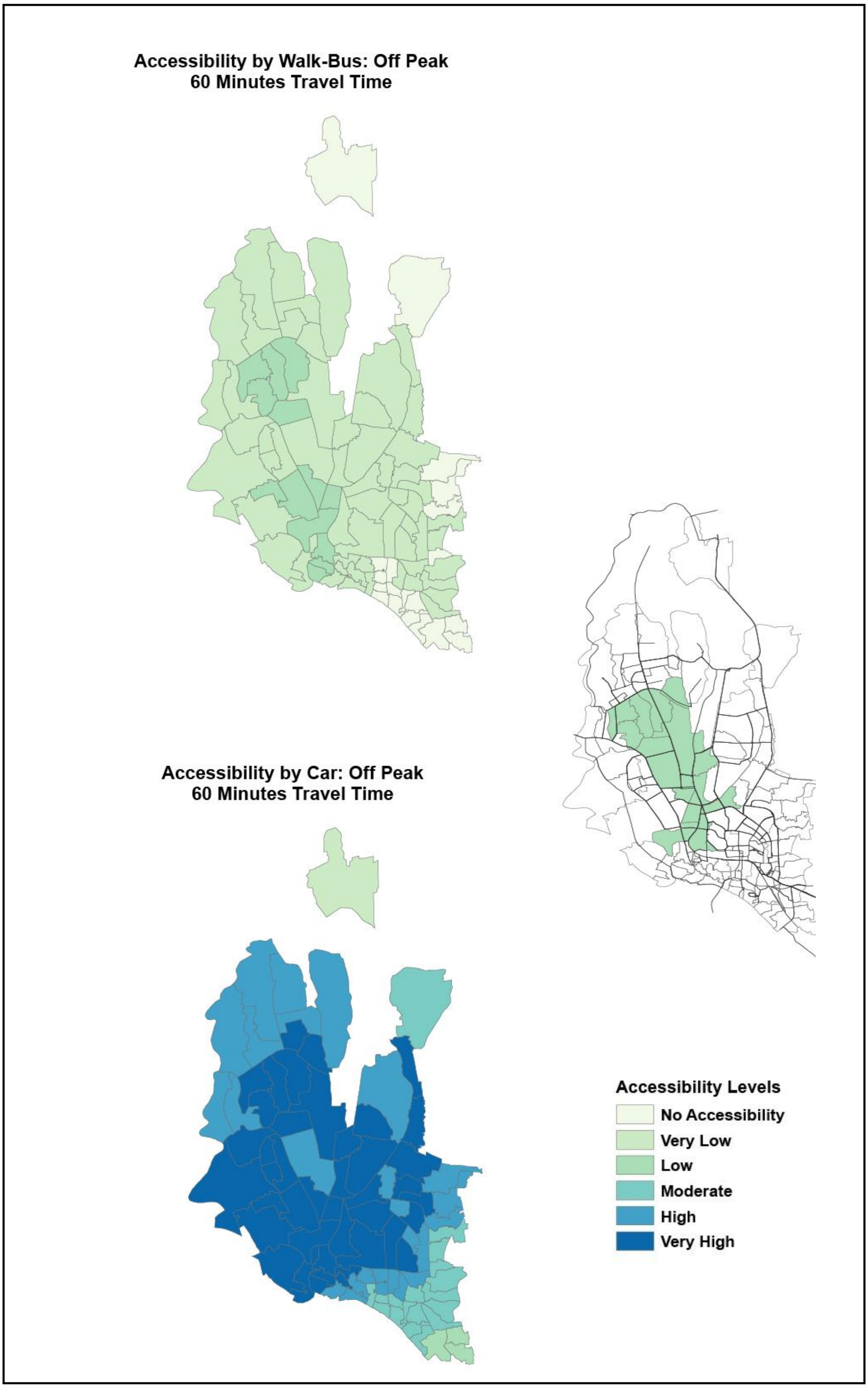

Figure 4.4 (f): Off peak accessibility at 60 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during off peak)

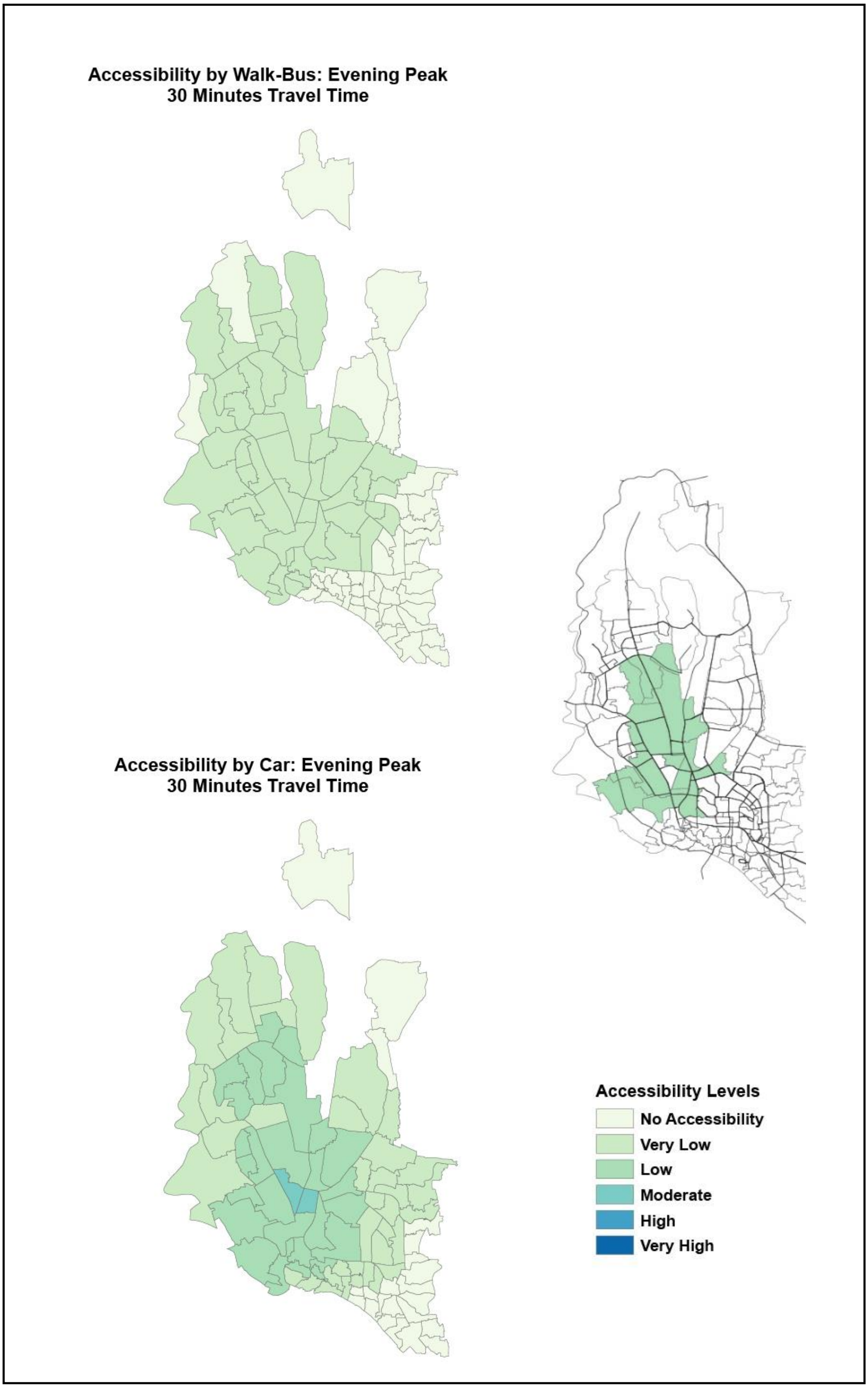

Figure 4.4 (g): Evening peak accessibility at 30 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during evening peak)

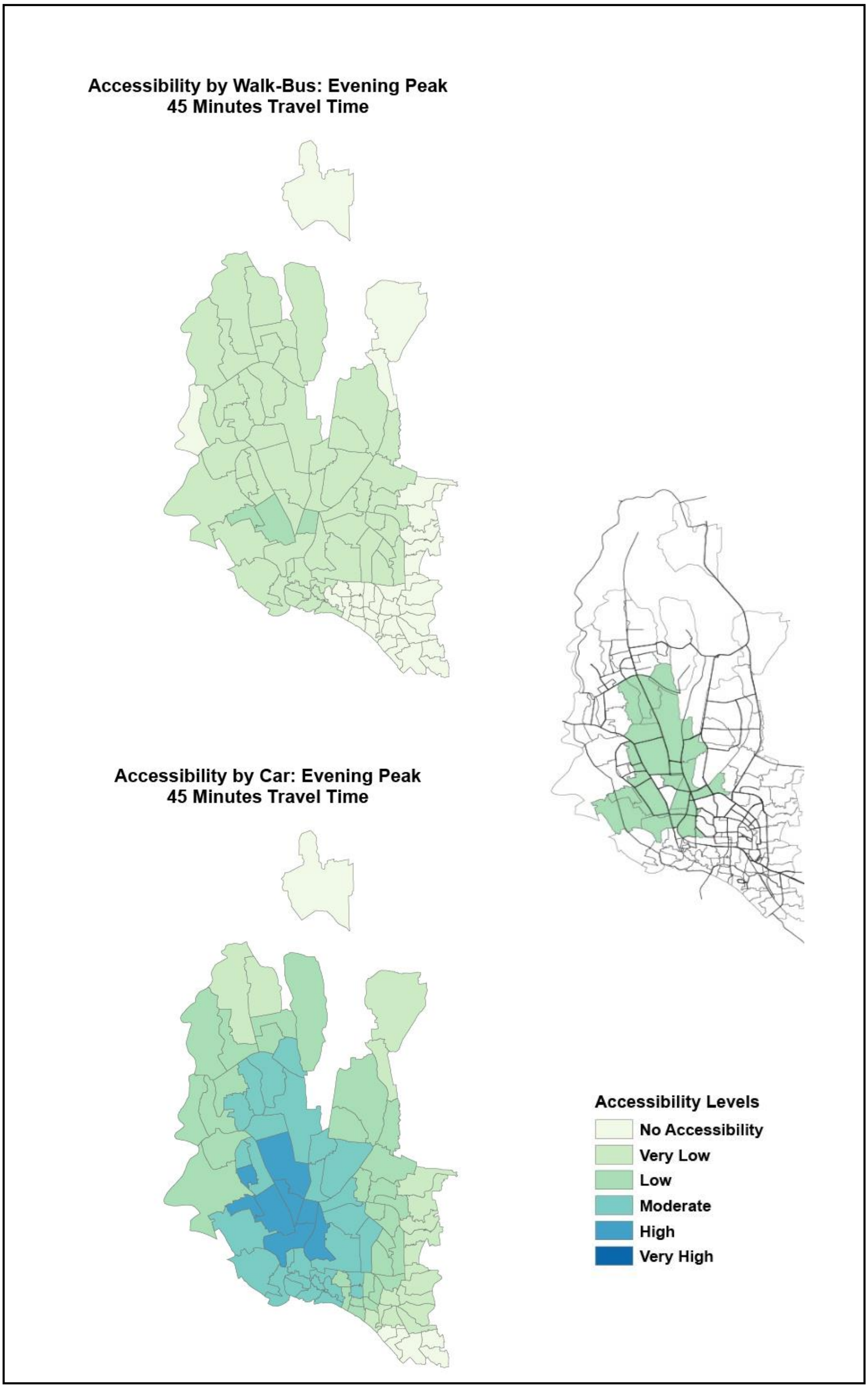

Figure 4.4 (h): Evening peak accessibility at 45 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during evening peak)

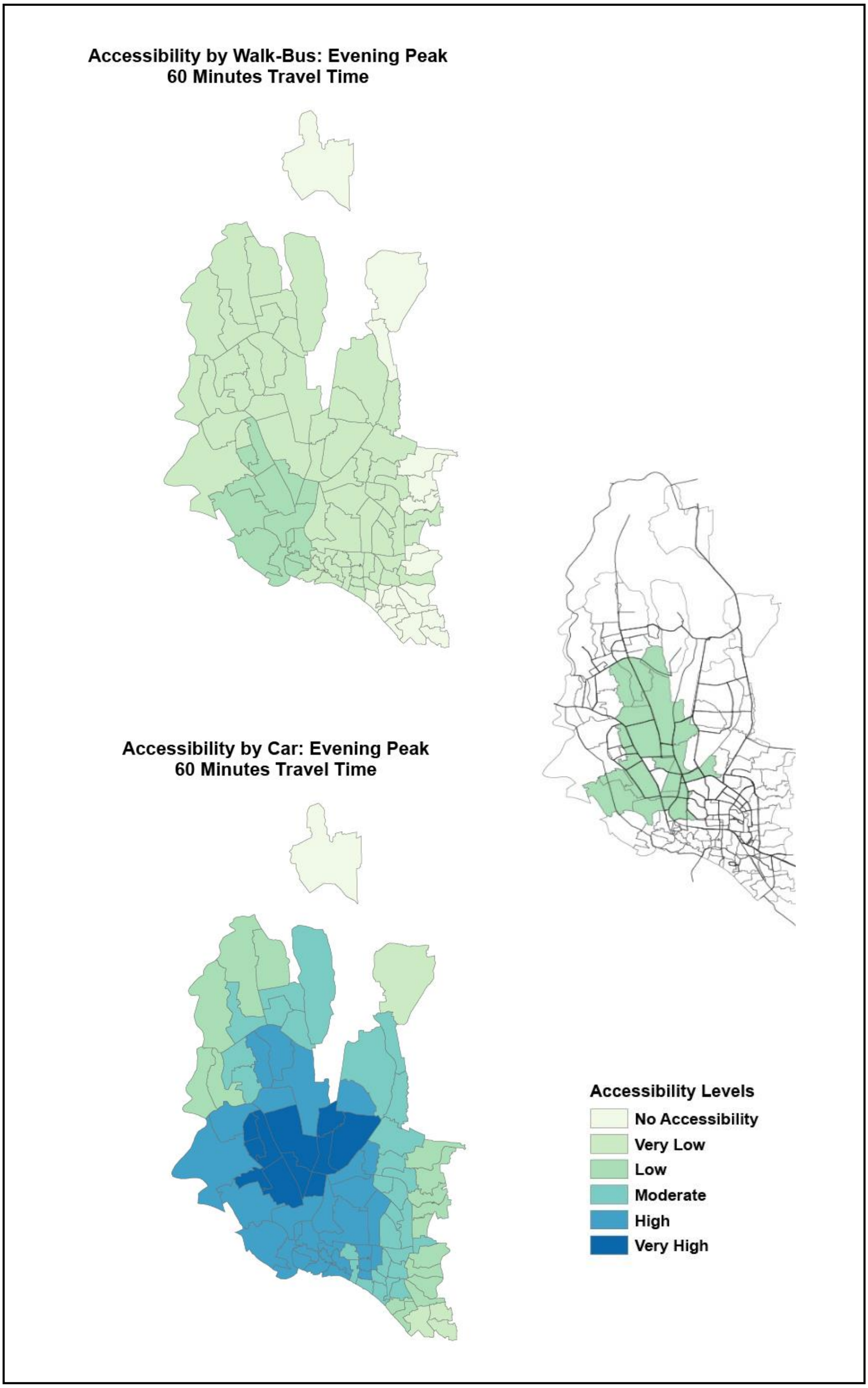

Figure 4.4 (i): Evening peak accessibility at 60 minutes cut-off travel time (top: multimodal accessibility, bottom: car accessibility; right: statistically significant major destinations during evening peak)

4.4.3 Accessibility Gap and Modal Mismatch

Proximity to Major Destinations and Accessibility

Being close to major destinations yield better accessibility for both car and bus users and understandably so. However, proximity to the major destinations is more crucial for bus users than car users. The scatter plots in the next page show the difference between car and multimodal accessibility of the TAZs with average distance from the major destinations **(Figure 4.5)**. Every TAZ has a pair of points in each of the scatter plots: one for car (in orange) and another for walk-bus (in blue). All the scatter plots tell similar story.

Multimodal accessibility is noticeably low compared to car even at small average distance from the major destinations. Low accessibility by walk-bus is ubiquitous in the entire city- so low that TAZs with no bus accessibility might be conveniently labelled as very high car accessibility **(Figure 4.4).** Moreover, accessibility by walk-bus falls to zero way too quicker than car. However, the most important observation here is that being far off from the major destinations still gives substantially better accessibility to car users compared to bus users residing relatively closer to them. Therefore, proximity to major destinations has substantially different effects on car and multimodal accessibility. The gap is so wide that no matter how nearby bus users live to major destinations, they are extremely unlikely to enjoy accessibility anything close to the car users. This echoes several previous studies, which found that travel mode plays a more important role than location in determining accessibility (Grengs et al., 2010; Hess, 2016; Kawabata, 2003a; Ong & Miller, 2005).

This supports the classic 'modal mismatch' theory from both spatial and temporal perspective: irrespective of where a person resides or when a trip is made, dependence on public transport puts them in a substantially disadvantageous position. Nearly 29% of the population enjoys high accessibility by at least 60 minutes of travel by car irrespective of time of day and location of major destinations. On the contrary, not even a small segment of the population can enjoy such accessibility by walk-bus all day long **(Table 4.2).**

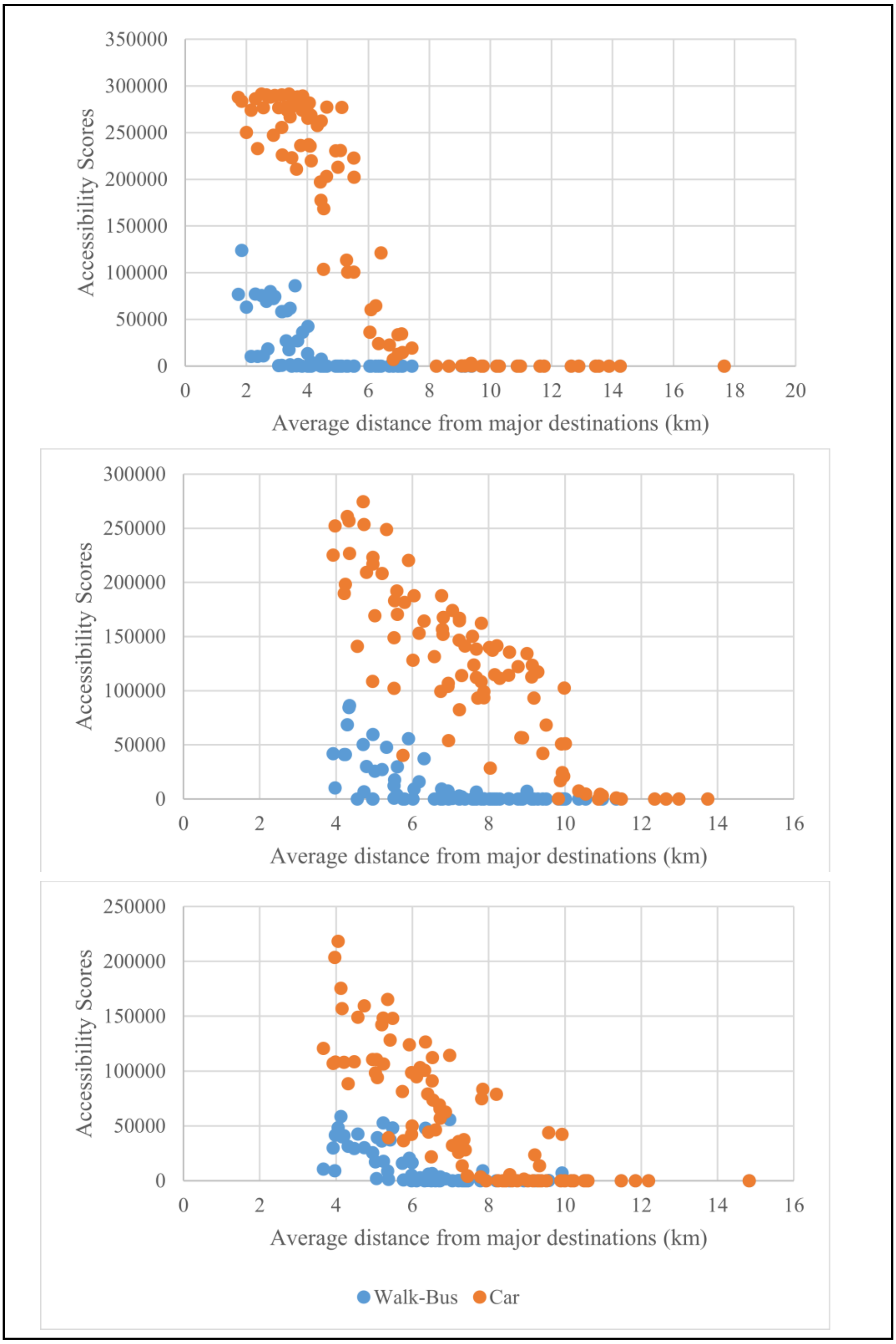

Figure 4.5 (a): Accessibility scores by average distance from major destinations at 30 minutes cut-off travel time during morning peak (top), off-peak (middle) and evening peak (bottom)

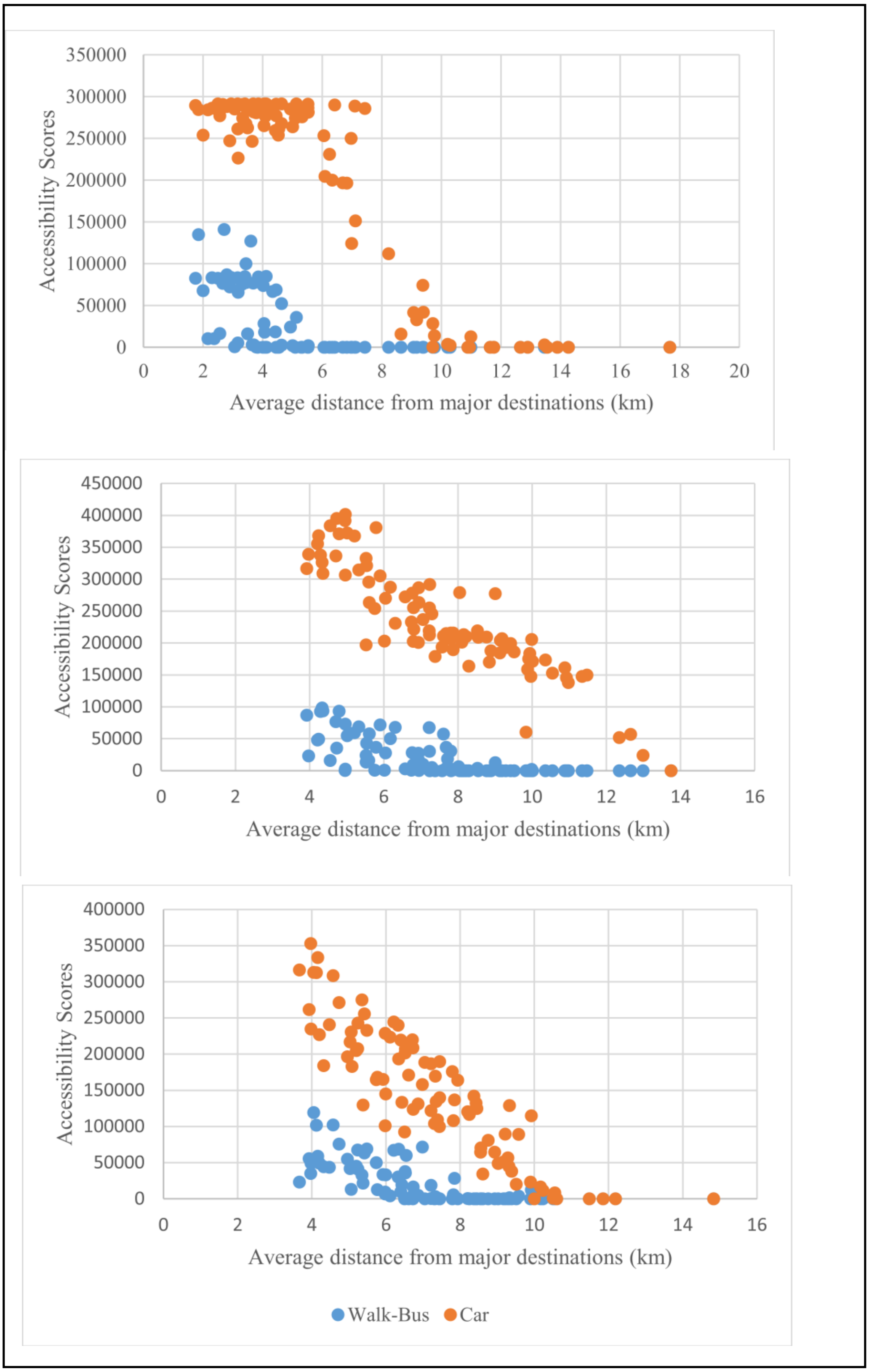

Figure 4.5 (b): Accessibility scores by average distance from major destinations at 45 minutes cut-off travel time during morning peak (top), off-peak (middle) and evening peak (bottom)

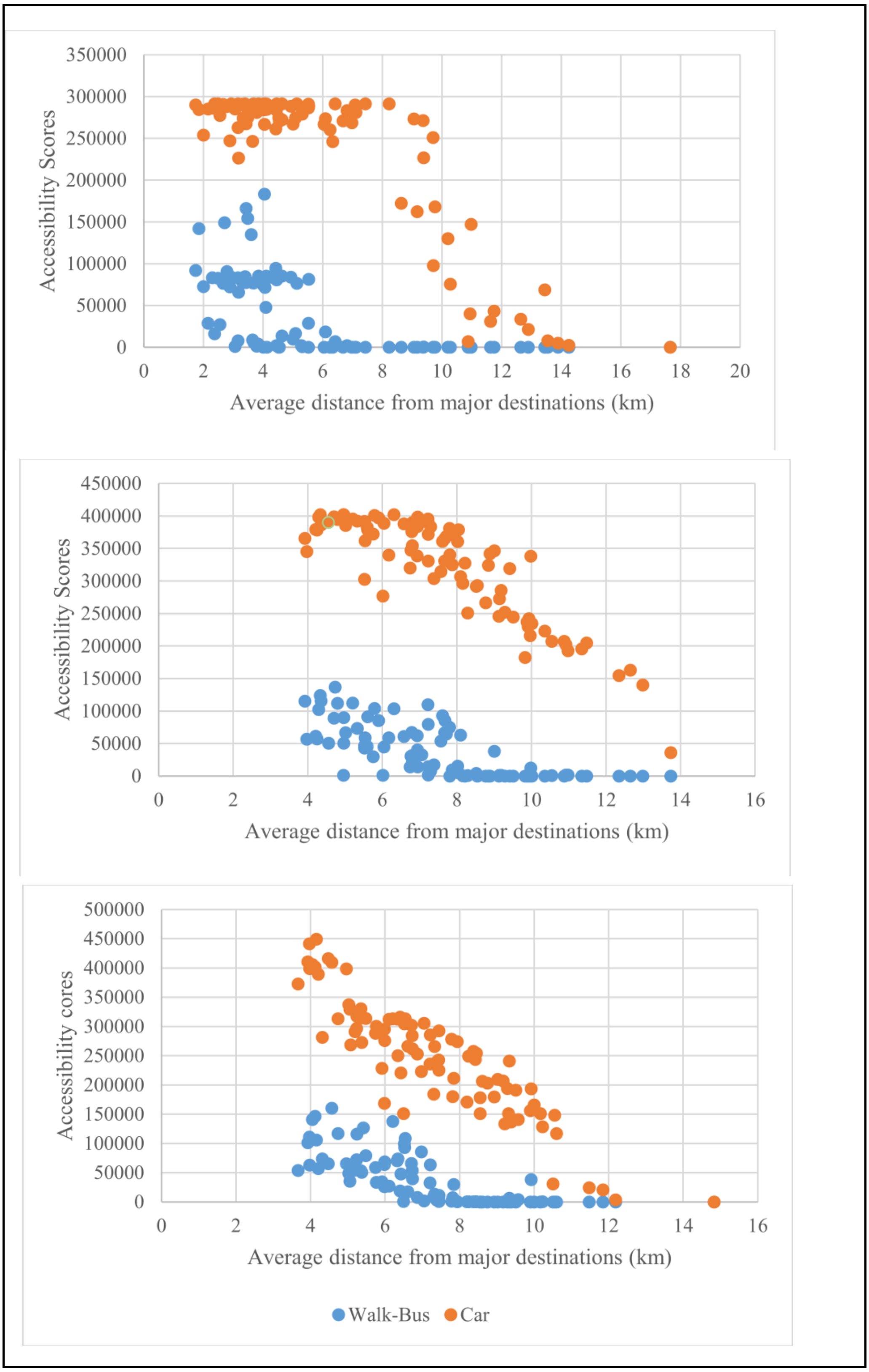

Figure 4.5 (c): Accessibility scores by average distance from major destinations at 60 minutes cut-off travel time during morning peak (top), off-peak (middle) and evening peak (bottom)

Spatial variation in job accessibility could be better understood from the standard deviation classification maps **(Figure 4.6)**. The accessibility scores have been presented as standard deviational categories with mean 0 and standard deviation 1. For simplified understanding, TAZs with accessibility score above the mean are considered as accessibility-rich locations (in shades of blue) and TAZs with accessibility score below the mean as accessibility-deprived locations (in shades of red). Some insights could be drawn from these maps. First, accessibility-rich locations are always markedly higher in number for car than walk-bus. Second, accessibility-rich locations are mostly clustered around the major destinations and accessibility-deprived ones are somewhat sparse. From the analysis so far, this is unsurprising. Third, with increasing travel time, accessibility-rich locations increase for both car and walk-bus. However, compared to walk-bus, these locations spread in the east-west direction far more quickly and noticeably for car. With increasing travel time, accessibility-rich locations spreads mostly towards north-south direction for bus. On the other hand, this spreading out takes place consecutively towards north-south and east-west directions for car. This phenomenon can be explained by the distinct characteristics of bus route network in the city. Network structure is a crucial factor in determining accessibility level- a well-developed and balanced transit network is a highly influencing factor in improving transit accessibility as well as ensuring similar accessibility scenario in almost all directions in a city (Ford, Barr, Dawson, & James, 2015; Niedzielski & Śleszyński, 2008). Absence of bus route connectivity in the east-west direction in the city is one of the most criticized aspects of public transport system in Dhaka. Here, the bus routes tend to extend in the north-south direction leading to poor connectivity and consequently low public bus accessibility in several parts of the city. Accessibility maps presented earlier do not explicitly capture this impact of bus route network structure on public transport accessibility. More precisely, those maps do not show any particular pattern of changing accessibility levels along the bus routes. But the standard deviation classification maps indicate that in line with several other studies where accessibility level changes along transit routes, in Dhaka as well, bus route network structure has some effect on multimodal accessibility (Boisjoly & El-Geneidy, 2016; Liu et al., 2018).

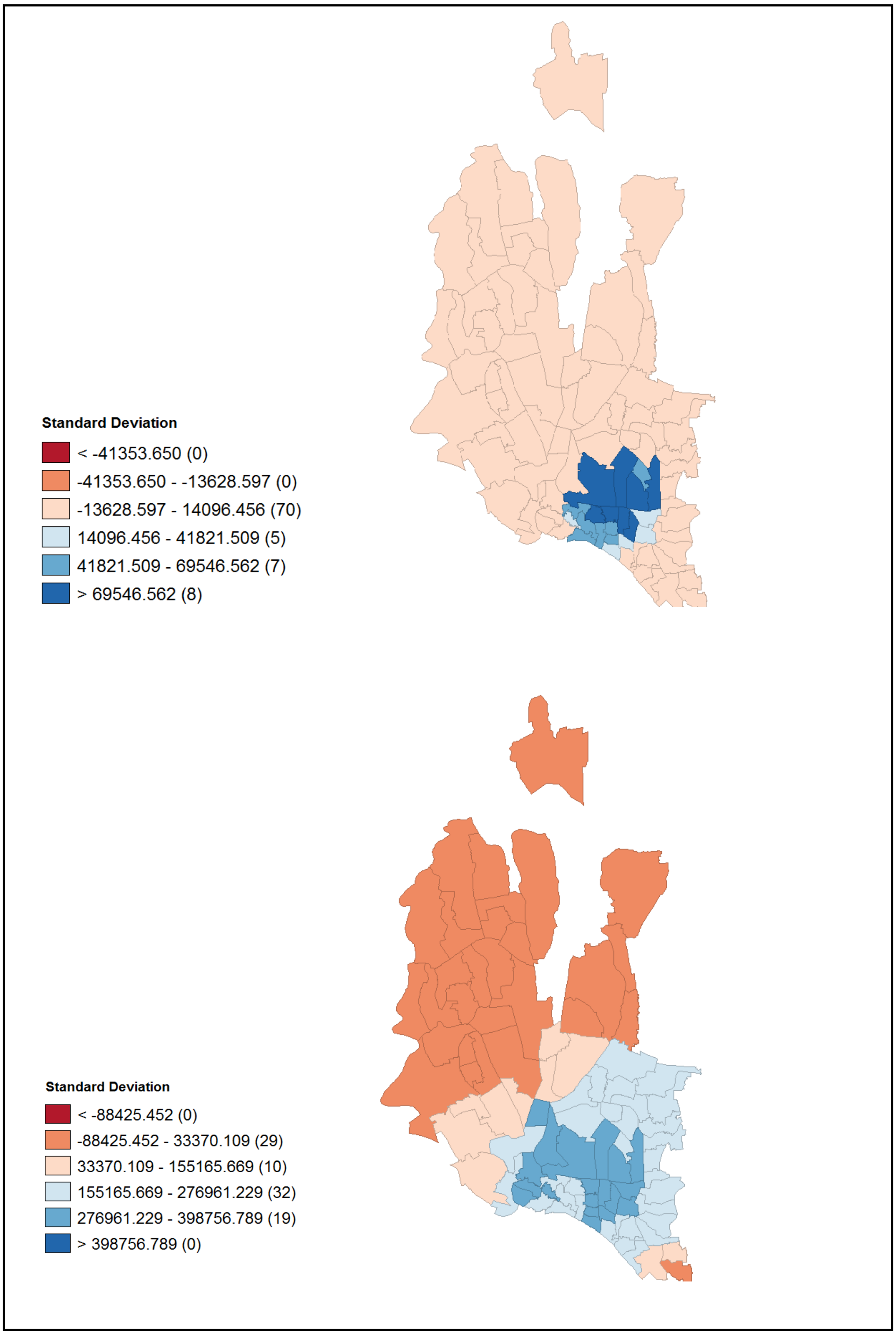

Figure 4.6 (a): Morning peak accessibility at 30 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

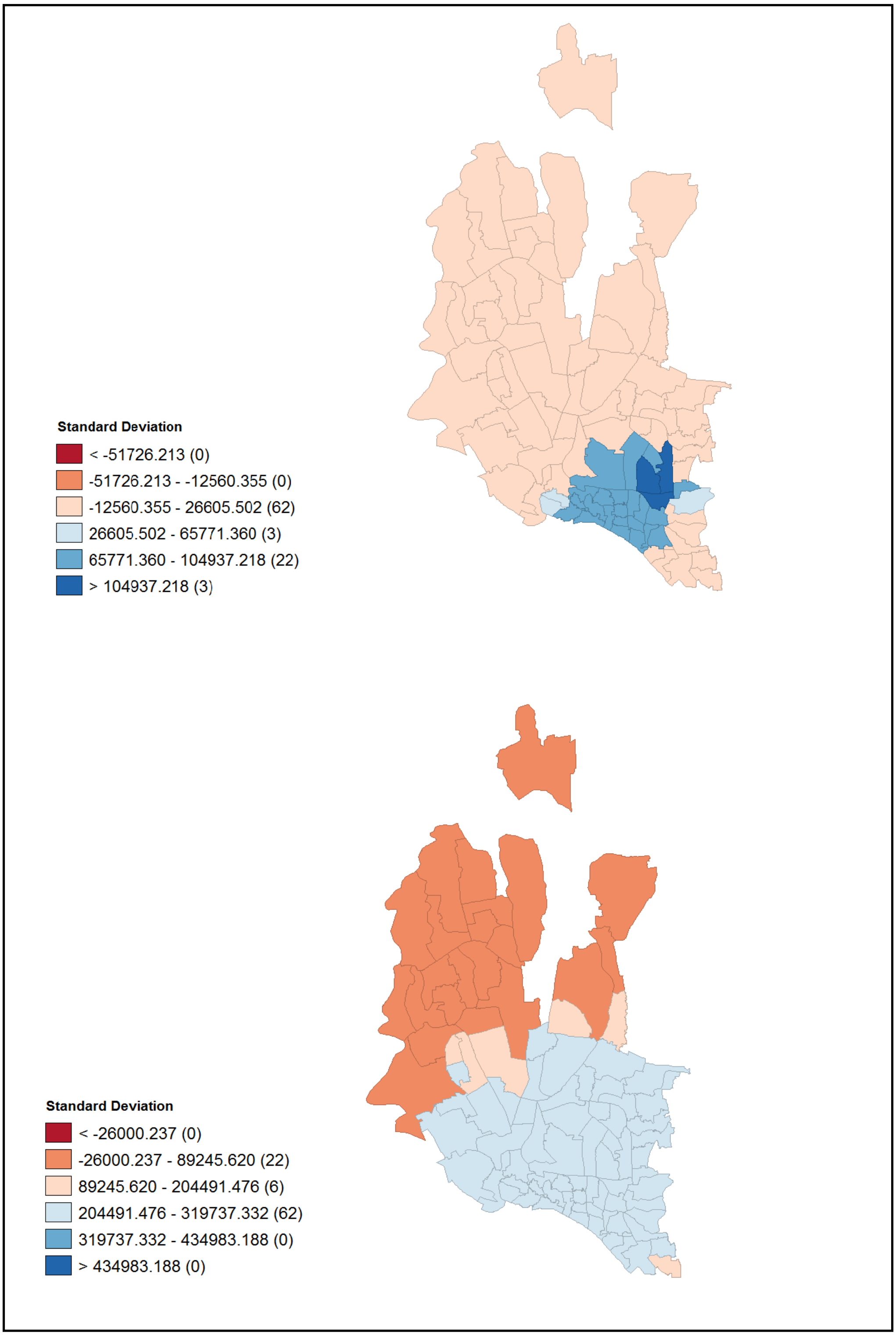

Figure 4.6 (b): Morning peak accessibility at 45 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

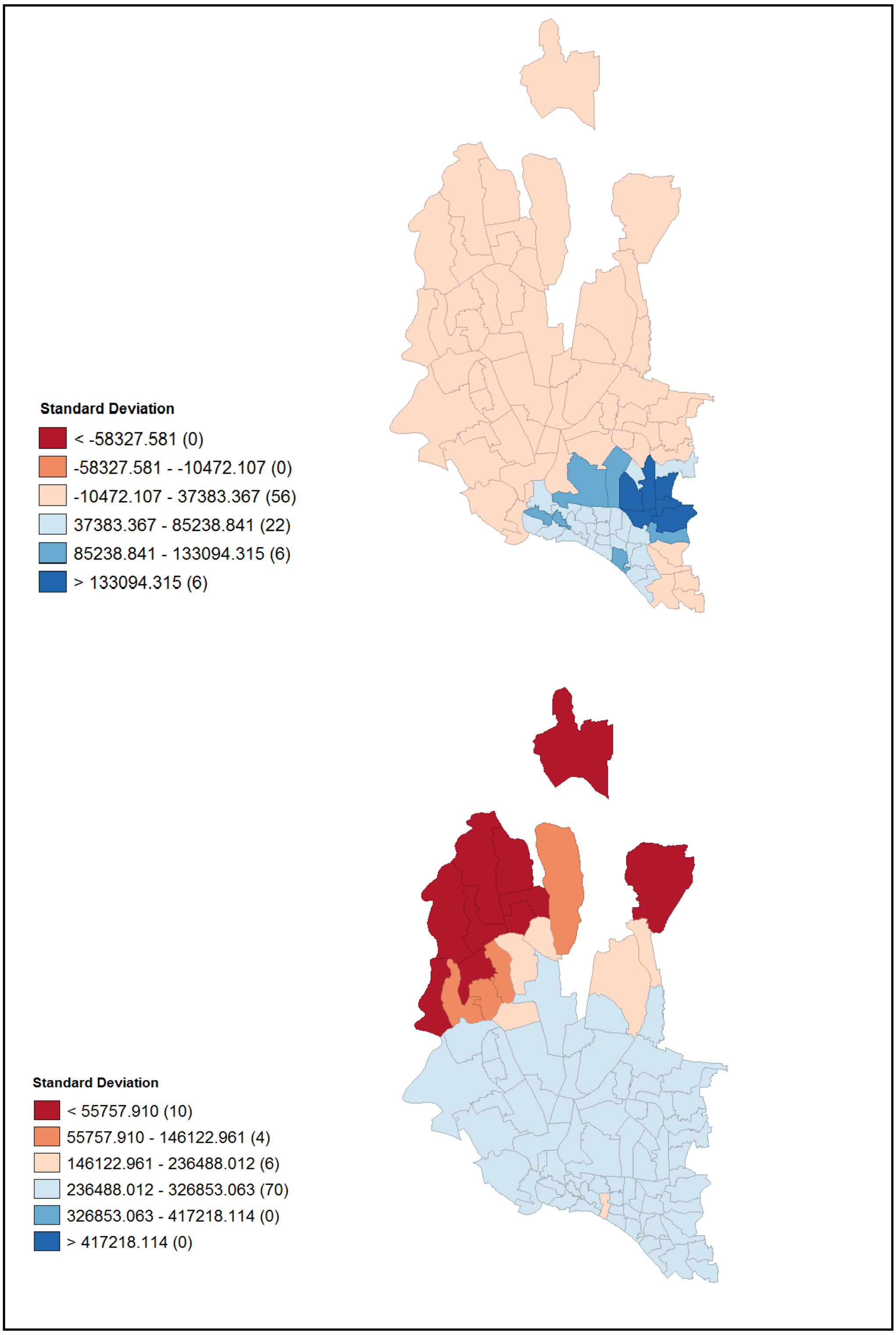

Figure 4.6 (c): Morning peak accessibility at 60 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

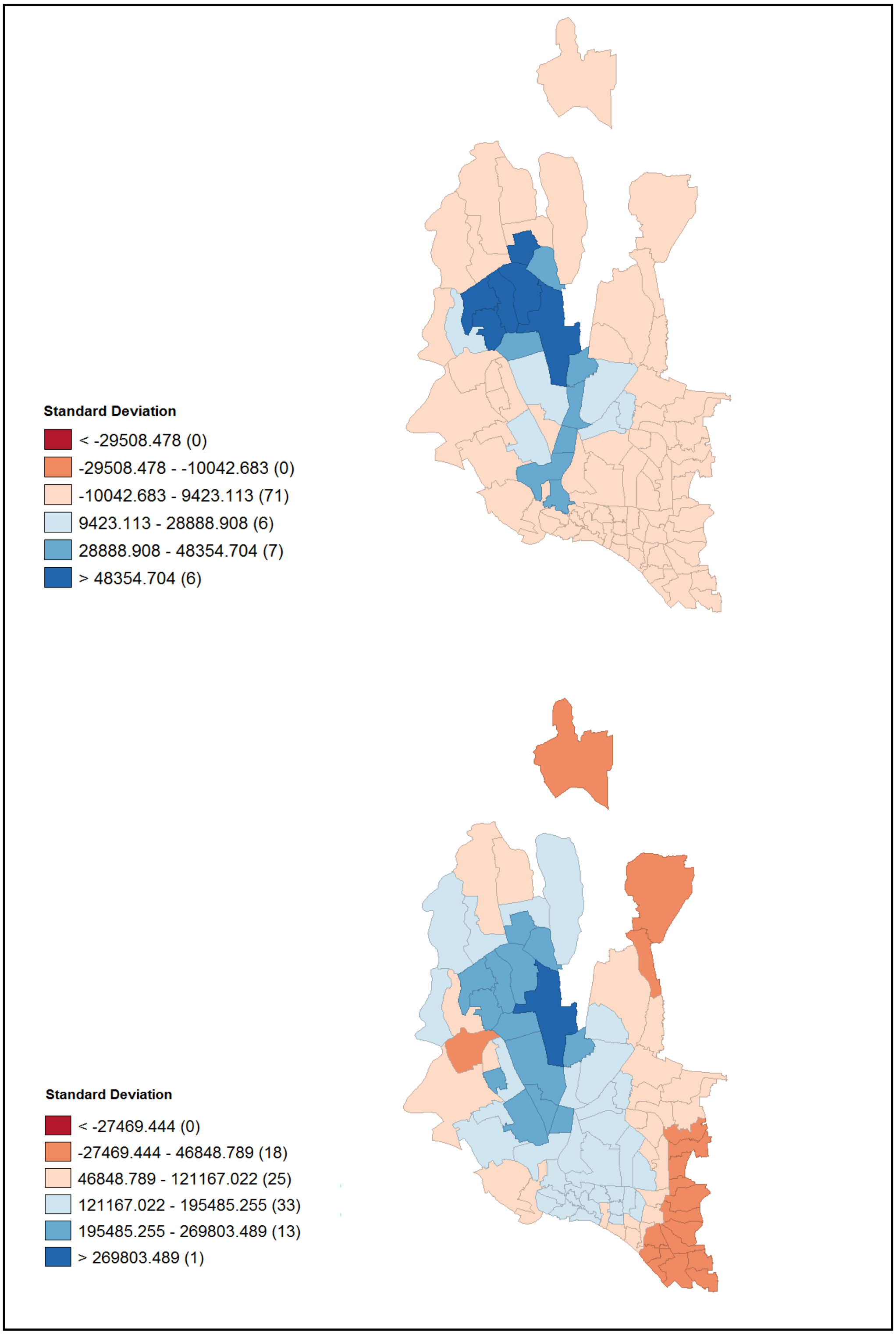

Figure 4.6 (d): Off peak accessibility at 30 minutes cut-off travel time-standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

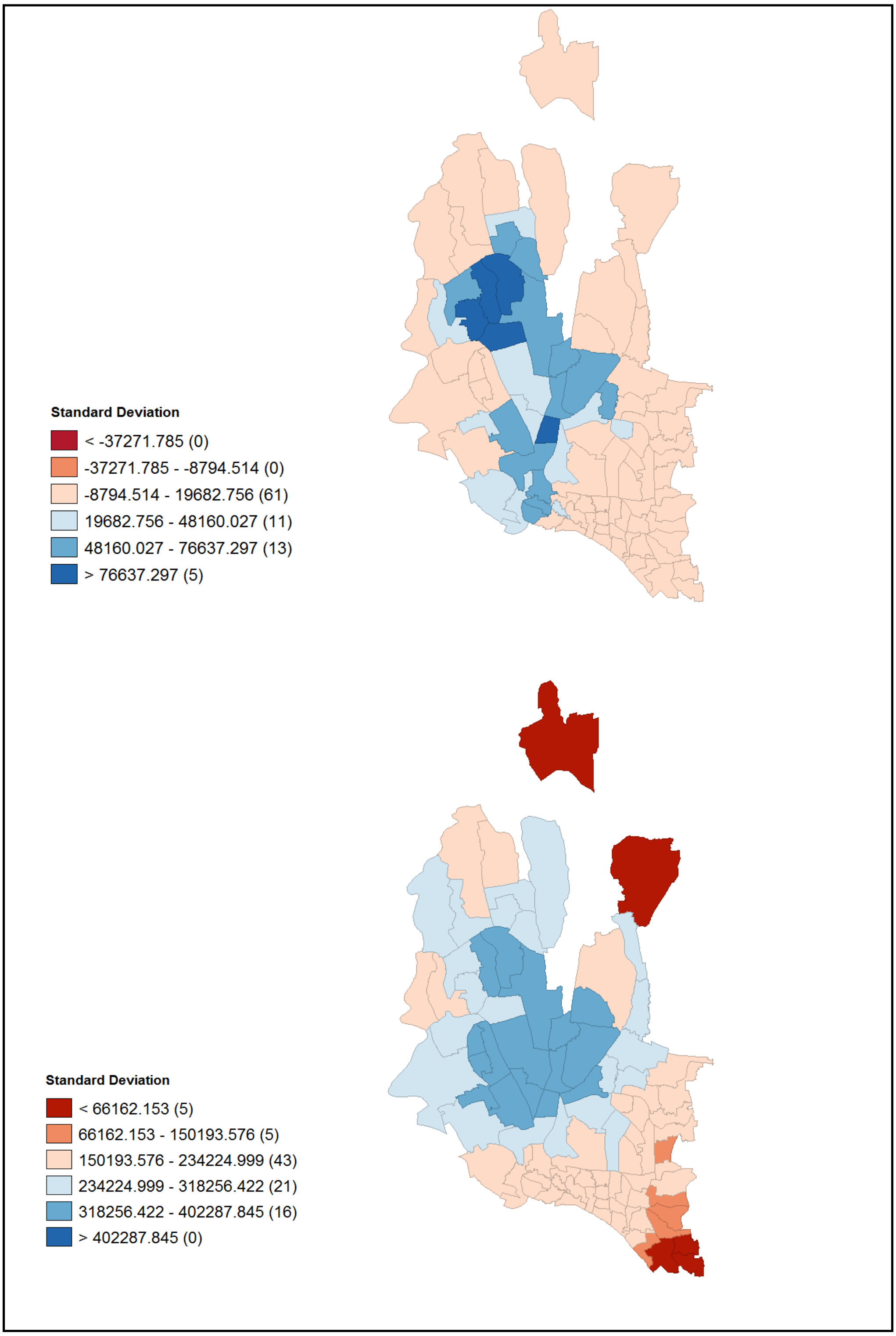

Figure 4.6 (e): Off peak accessibility at 45 minutes cut-off travel time-standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

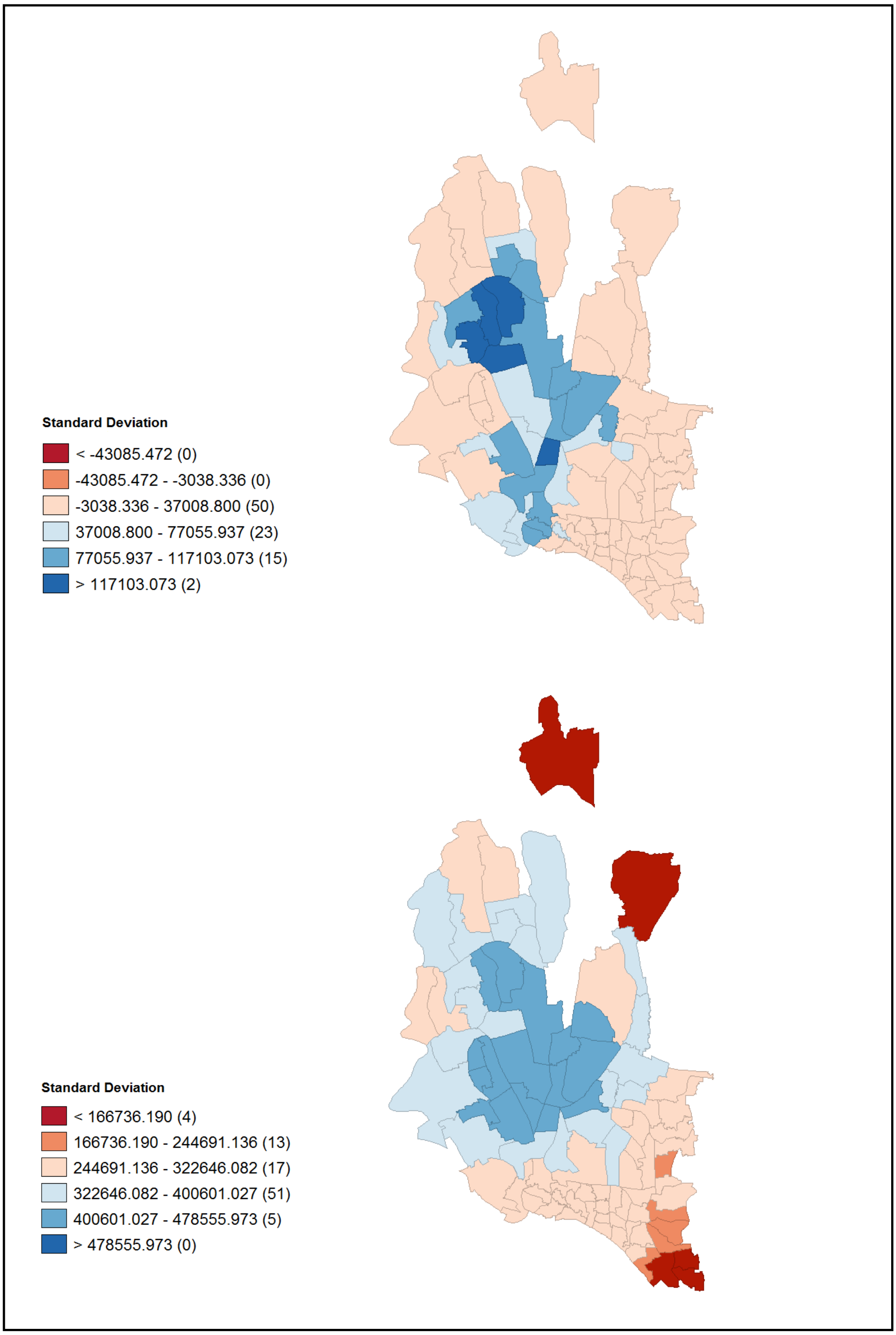

Figure 4.6 (f): Off peak accessibility at 45 minutes cut-off travel time-standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

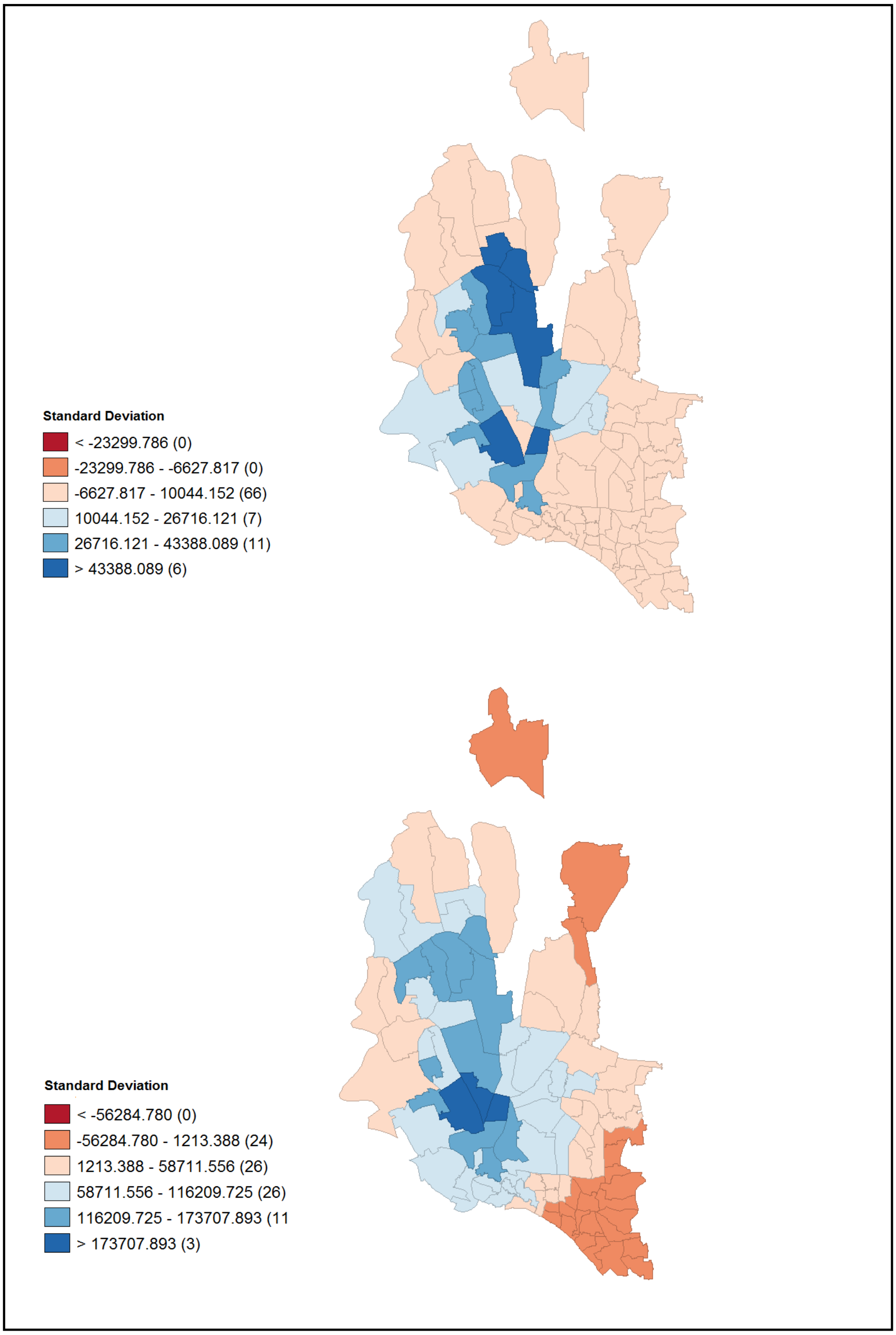

Figure 4.6 (g): Evening peak accessibility at 30 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

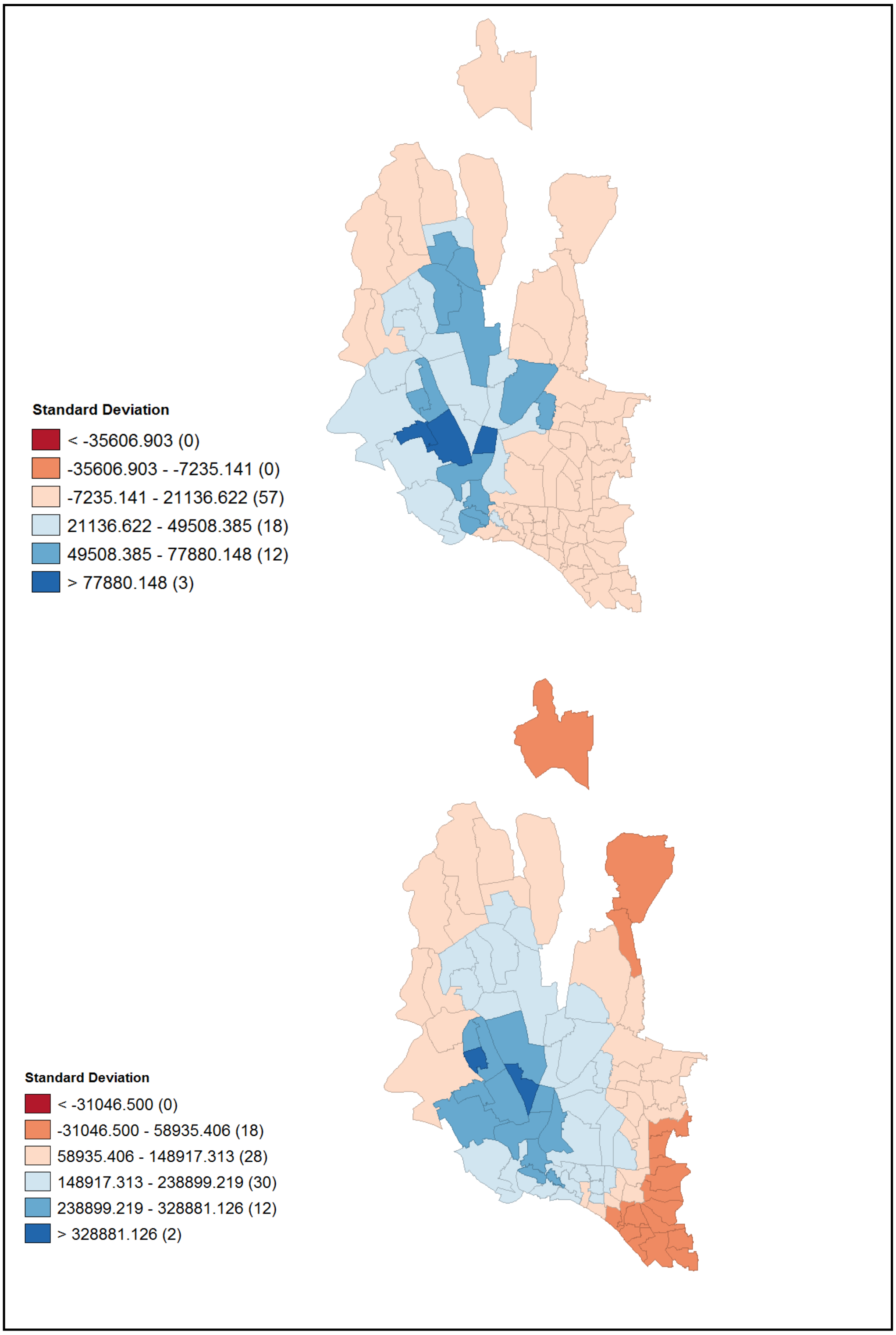

Figure 4.6 (h): Evening peak accessibility at 45 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

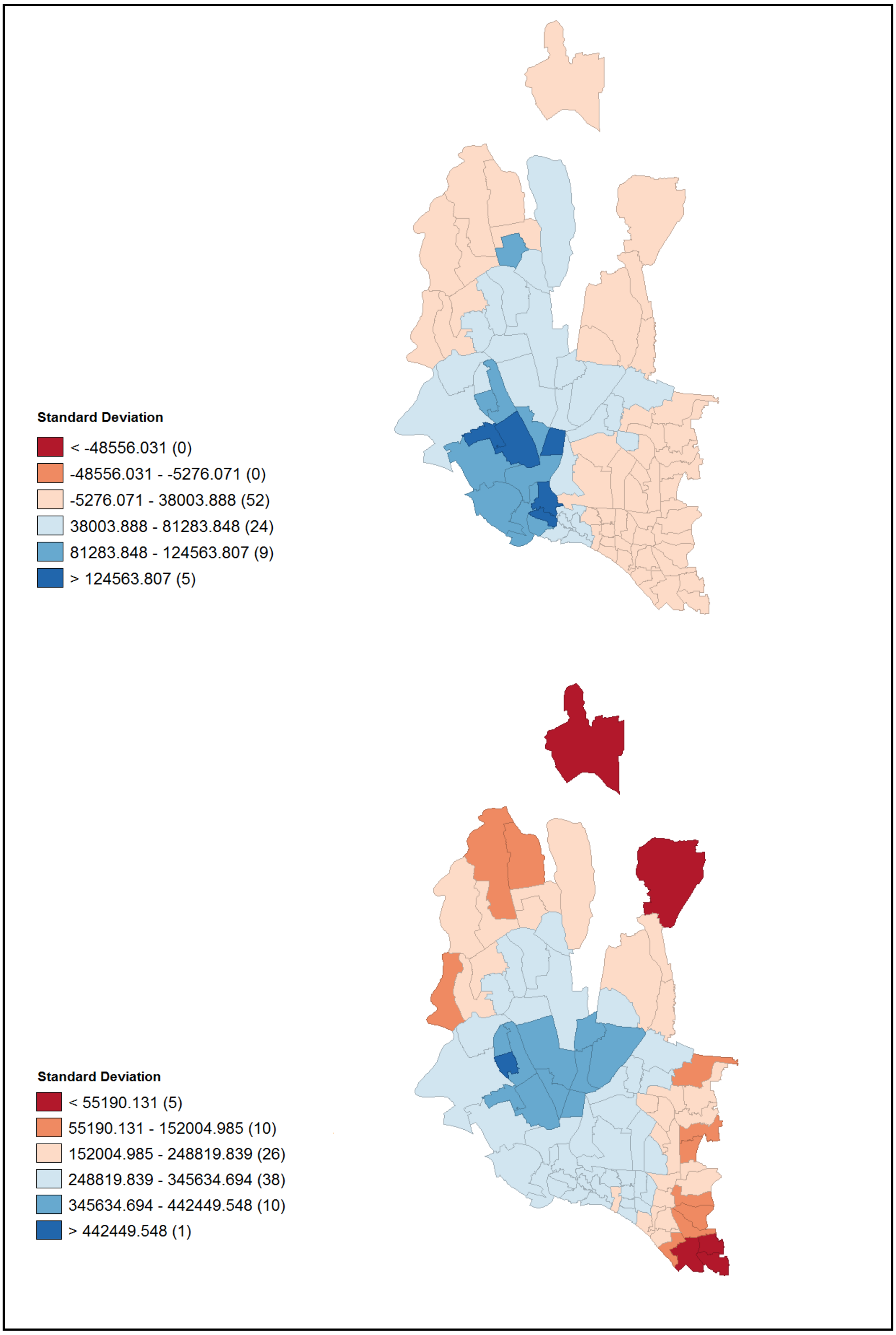

Figure 4.6 (i): Evening peak accessibility at 60 minutes cut-off travel time- standard deviation classification (top: multimodal accessibility, bottom: car accessibility)

Modal Accessibility Gap

To confirm the observations and findings of difference in accessibility by car and bus, it has been tested whether the difference is statistically significant. The data do not follow normal distribution due to a considerable number of TAZs with accessibility score of 0, especially at lower cut-off travel times and by walk-bus. Therefore, a non-parametric sign test was performed for each of the 9 pairs. For all the pairs it was found that car accessibility is statistically significantly greater than walk-bus accessibility (p=0.000 for each pair).

Next, to have a closer look at the accessibility gap at TAZ level, Modal Accessibility Gap (MAG) was calculated using **Equation 3**.

Table 4.4: Average Modal Accessibility Gap between Car and Walk-Bus

	30 minutes	45 minutes	60 minutes
Morning Peak	0.88	0.84	0.81
Off-peak	0.82	0.82	0.78
Evening Peak	0.69	0.72	0.71

Average MAG values are close to 1 indicating very poor accessibility by walk-bus throughout the day. The gap between multimodal and car accessibility tends to decrease with increasing cut-off travel time (the only exception is 30 and 45 minutes cut-off travel time during evening peak) **(Table 4.4)**.

This phenomenon of spatial smoothing with longer travel time is consistent with several previous studies (Kawabata, 2009; Kawabata & Shen, 2006; Kawabata & Takahashi, 2005; Luo & Wang, 2003). This is likely because the effect of walking and waiting time for public transit do not necessarily change with different cut-off travel times. Public transit travel is highly constrained by specific scheduling and routes. Moreover, the first/last mile transit access involves a considerable portion of total travel time (Boarnet et al., 2017). These are, in a nutshell, reasons for comparatively lower public transit accessibility than car in any city. Therefore, as the effect of walking and waiting time do not always increase with increasing travel time, the difference between public bus and car accessibility tends to narrow.

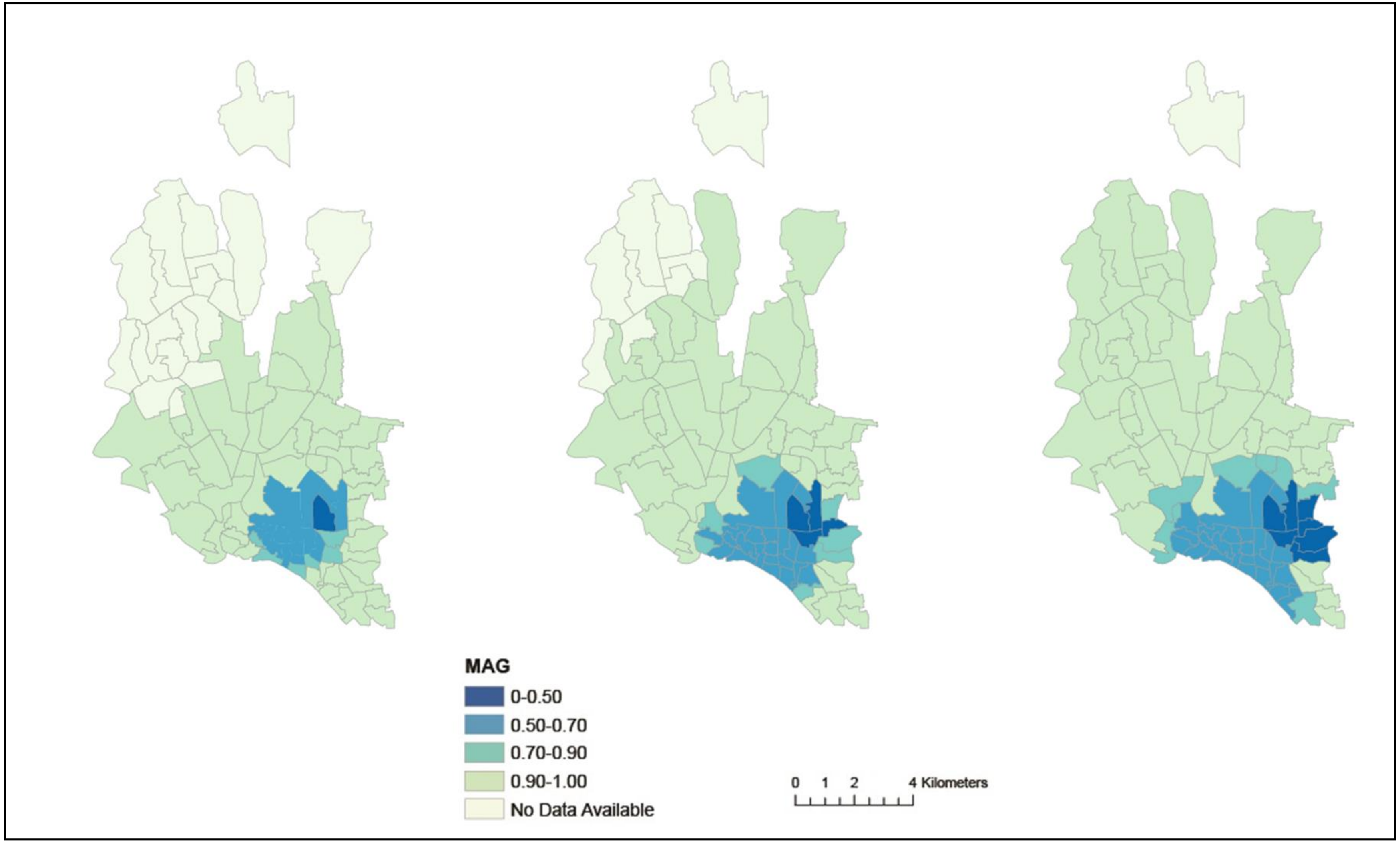

Figure 4.7 (a): MAG during morning peak at 30 minutes (left), 45 minutes (middle) and 60 minutes (right) cut-off travel time

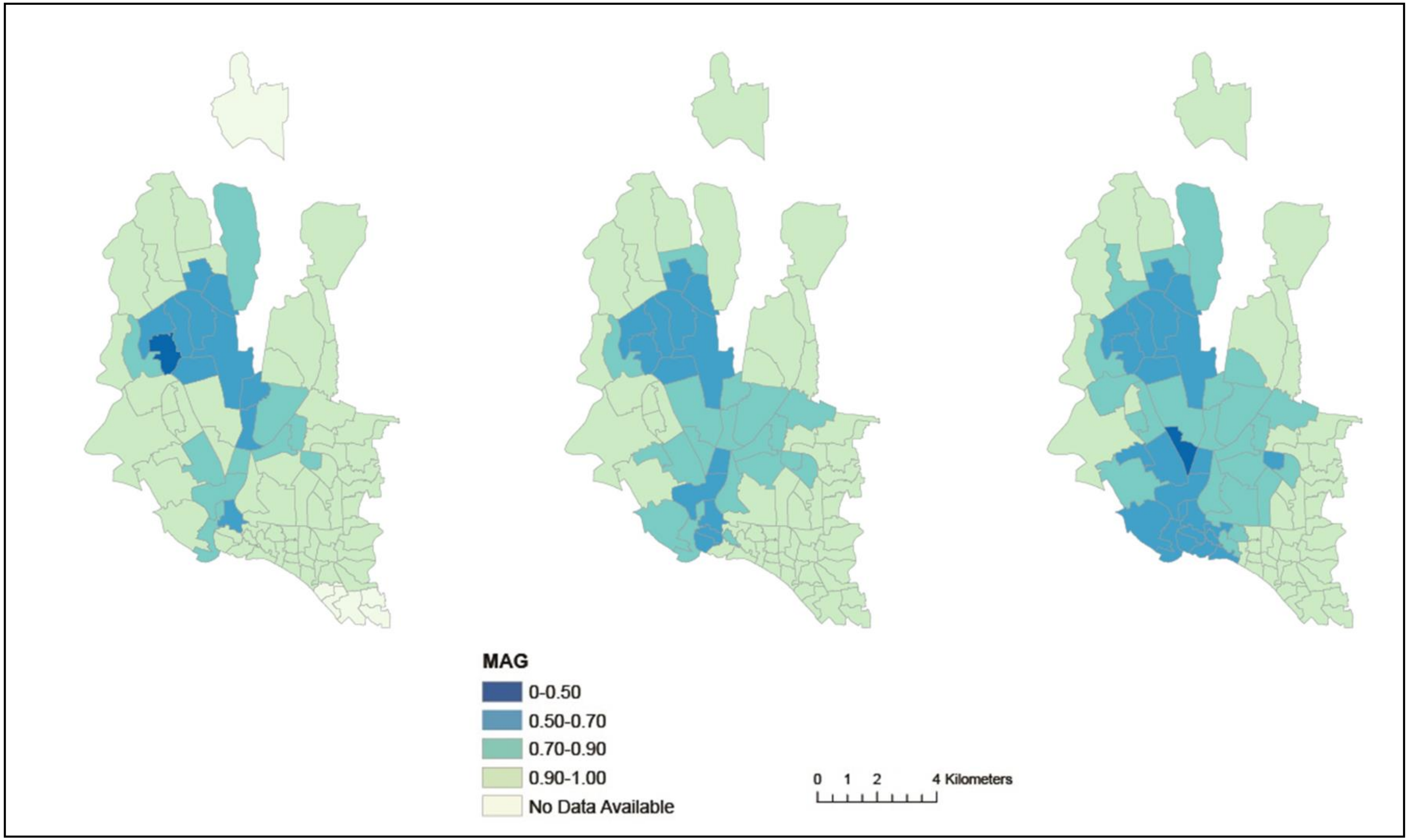

Figure 4.7 (b): MAG during off-peak at 30 minutes (left), 45 minutes (middle) and 60 minutes (right) cut-off travel time

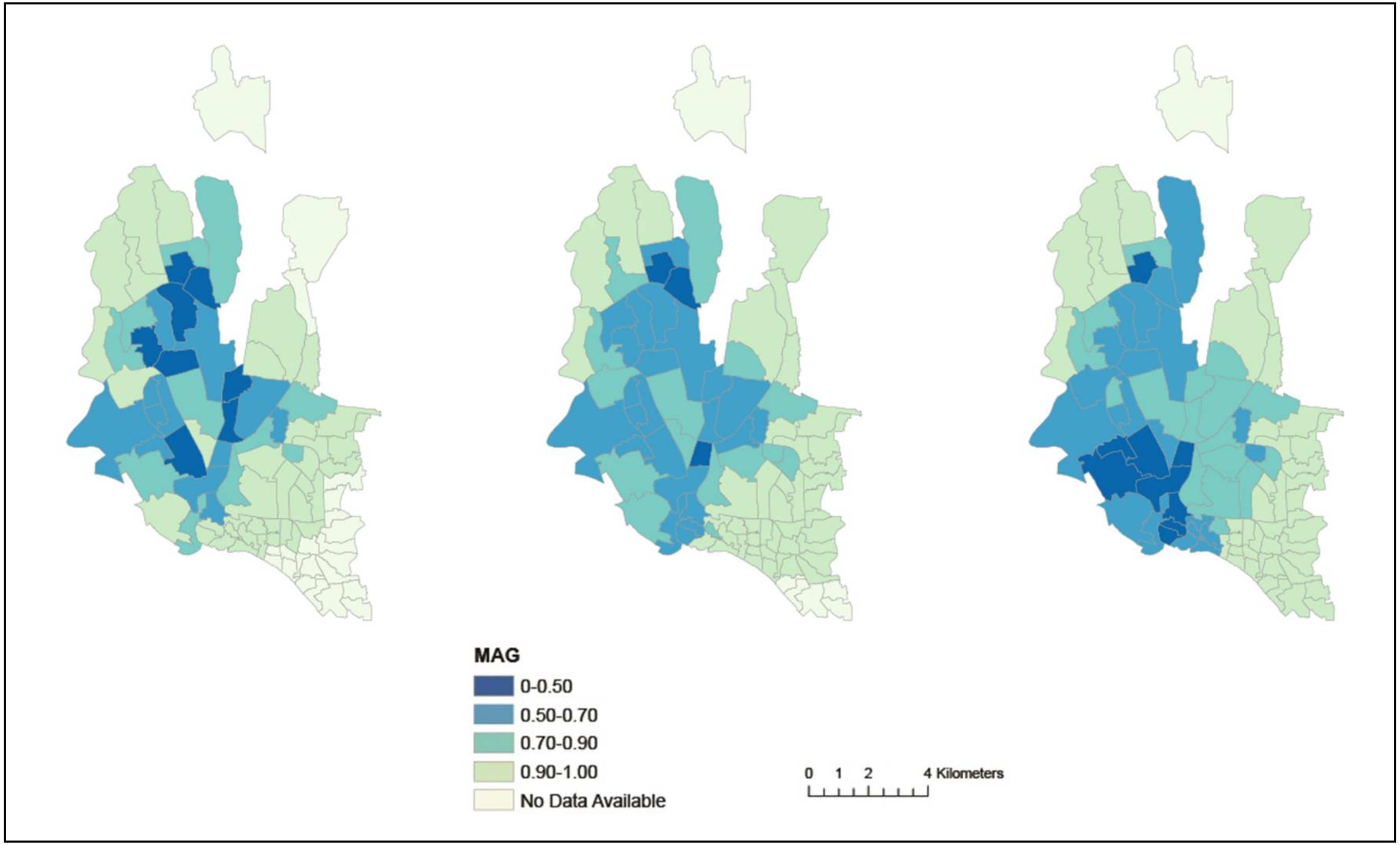

Figure 4.7 (c): MAG during evening peak at 30 minutes (left), 45 minutes (middle) and 60 minutes (right) cut-off travel time

In general, MAG increases as the TAZs spread outward from the major destination clusters irrespective of time-of-day **(Figure 4-6)**. This is consistent with the discussion so far that proximity to major destinations has substantially different effect on car and bus. During off and evening peak in particular, with increasing travel time, modal accessibility gap increases for some TAZs **(Figure 5-6)**. This indicates that having more reachable opportunities with increasing travel time does not always reduce the accessibility gap for individual TAZs. Rather it may sometimes widen the gap by simultaneously making a disproportionately higher number of opportunities available by car.

The statistically significant major destinations by peak and off-peak hours confirm that morning, off and evening peak hour trips often cluster in different locations within the city. Hence, living in proximity to morning peak hour cluster may make the journey to work easier for transit riders, but not the non-work trips. A similar thing can be said for other time-of-days.

On the flip side of the coin, private car gives way more freedom, flexibility and ease of overcoming the friction associated with travel (Blumenberg & Manville, 2004). The unsurprising result is greater freedom and ease in reaching both work and non-work activities. Public bus users are, therefore, disadvantaged throughout the day more due to the mode they use and less due to the location of residence or time of travel.

4.5 CHAPTER SUMMARY AND KEY TAKEAWAYS

In this study, it has been attempted to highlight the potential of considering temporal dimension in accessibility analysis even under settings where no specific public transport schedule is available, not to mention the resulting lack of regulated and well-maintained public transport database. Whereas it is customary these days to use the dynamic and comprehensive GTFS database in evaluating accessibility in developed countries, developing countries like Bangladesh is still far away from such database or public transit structure (Cui et al., 2019; Farber et al., 2014; Stępniak, Pritchard, Geurs, & Goliszek, 2019; Widener et al., 2017). Therefore, incorporating temporal dimension is a challenging task in such a status quo. Nevertheless, the importance of temporal dimension does not diminish under such settings. Thus, by identifying major destinations by time-of-day, it has been tried to find an alternative to integrate temporal dimension along with spatial dimension in accessibility evaluation under data-deprived context like ours. The locations where a large number of trips are made in different hours of the day were identified. Therefore, the approach and findings of this study is an addition to the accessibility-related research under such settings.

While interpreting the results, it should be kept in mind that statistically significant major destinations are different for different times of the day. Thus, the number of available opportunities is different as well. A change in accessibility for a certain TAZ from one time-of-day to another can be due to the difference in travel speed, difference in total employment opportunities available in the major destinations or the combined effect of these two. Therefore, care should be taken while comparing results across different times of the day. Caution should also be taken in interpreting the major destination clusters themselves. It is possible for any individual TAZ to attract a high number of trips but given the methodology adopted, it is also possible that the TAZ is not a major destination if it is not surrounded by other high trip attracting TAZs. Therefore, it should not surprise the reader if any individual typical 'activity hub' TAZ does not appear to be a major destination here.

The study has encountered limitations in data. It was dependent on employment data only assuming that it would serve as a representative base for all facilities. A more accurate picture could be portrayed if a reliable database of other relevant facilities were available for Dhaka. However, it is expected to serve as a solid starting point to understand spatiotemporal variation in accessibility with limited data availability. At the same time it is noteworthy to point that the relevance of access to job opportunities is not limited to work trips only because a workplace for one person often offers different other opportunities to another person e.g. recreation, healthcare, shopping, etc. (Merlin, 2017).

Accessibility by car might also be slightly overestimated since time spent for parking cars was not available. However, given the huge modal accessibility gap, this should not make much of a difference. One can argue as well on the relevance of ignoring the opportunities available in destinations other than the major destinations. The approach outlined in this paper has been chosen to prioritize policy implications. When a large amount of public money is spent on providing services and building new infrastructure, it is imperative to ensure that the money is used in the right place, on the right time and for the most deserving people – who have limited options and need it the most. The major destinations point to those locations where people go the most and therefore, those destinations needs to be served well by public transport as a priority to increase social equity and reduce pollution and congestion. The time-of-day approach could help in developing a well-connected bus route and reliable schedule system not only for mandatory trips but also for discretionary trips which are essential for the city. By saying that, the intention is not to underestimate the importance of improving public transport service in other locations. Rather it is simply intended to point out what the policymakers should emphasize and where the investments should go first. For example- policy and planning responses to this might include investing in new and improved public transport infrastructure and services that enhance accessibility to the major destinations, scheduling bus services based on demand by time-of-day, introduce new bus routes eliminating overlapping, planning for polycentricity instead of a monocentric city, etc.

To the author’s best knowledge, studies on accessibility addressing the interlink of trip purpose, time-of-day and trip destinations in an urban area are rare (Currie, 2004). Yet, considering this interlink and multimodality of public transport simultaneously is even rarer. Given the limited data availability, the approach of identifying major destinations by different times of day is particularly important to get an understanding of, along with work trips, accessibility scenario of several discretionary activities, e.g. healthcare, shopping, social relations, recreation, etc., which are essential parts of human life as a social creature. Down that line, this approach further leads to an insight that very few locations are equally accessibility rich or deprived all day around. Locations that enjoy good accessibility during peak working hours might suffer from poor accessibility when it comes to availing opportunities like healthcare or shopping.

This study illustrates that multimodal accessibility is significantly lower than car during any time-of-day. The modal accessibility gap between car and walk-bus is striking. The findings of the chapter are consistent with the ‘modal mismatch' concept and illustrate that mode of travel has a far greater impact than the location in determining accessibility irrespective of the locations of major destination clusters and time-of-day. The policymakers and urban planners need to carefully consider these issues and this study provides a starting point for this particularly for developing countries like Bangladesh. This methodological insight could be valuable for other developing regions as well.

Chapter 5

Travel Behavior in Dhaka City

5.1 INTRODUCTION

This chapter provides an overview of travel behavior in Dhaka city. Following the conceptualization of major destinations in the previous chapter, this chapter will depict a scenario of travel behavior to major destinations along with comparative overview of travel behavior in general in the city. The first section consists of descriptive statistics. Later on, mode choice for work and non-work trips and household car ownership models will be presented.

5.2 OVERVIEW OF TRAVEL BEHAVIOR IN DHAKA

After accounting for missing or inconsistent data from the DHUTS HIS database, a total of 74,215 trips have been included in the analysis. Out of those, 10,624 were made to major destinations.

A large percentage of trips are made for homeward purpose **(Table 5.1)**. Non-work trips which include shopping, social, recreation, medical, and religious, etc., outnumber work trips in general. This is an important finding since non-work trips often receive significantly lesser attention than work trips, particularly in the context of developing countries. This finding also strengthens the proposition in the previous chapter about the importance of non-work trips: the identification of major destinations in this study is, thus, an improvement over our typical emphasis on work trips and Central Business Districts (CBDs) that often disregard the non-work trips.

There is statistically significant difference in both average travel time and distance between trips to major destinations and other destinations. The average travel time to major destinations is 4.48 minutes higher than that of to other destinations ($t_{13949.98}$= 17.73, $p<0.001$) and the average travel distance to major destinations is 0.65 km higher than that of to other destinations ($t_{14240.1}$= 21.38, $p<0.001$) **(Table 5.2)**. This indicates that people travel further and for longer time to reach the major destinations suggesting the relative importance of the major destination clusters in offering important services and facilities to the city dwellers.

Table 5.1: Distribution of Trips by Purpose

Purpose	All Destinations	Major Destinations	Destinations other than the Major Destinations
Homeward	42.9%	42.1%	43.0%
Work*	22.4%	24.5%	22.0%
School	11.2%	6.3%	12.0%
Non-work	23.6%	27.1%	23.0%

*includes self-employment trips

Therefore, the major destination clusters have important policy implications e.g. new infrastructure investments may focus on enhancing accessibility to these TAZs, public transport schedule may be developed concentrating on these destinations and time-of-day, etc.

Table 5.2: Average Travel Time and Distance by Purpose and Destinations

	All Destinations	Major Destinations	Destinations other than the Major Destinations
Average Travel Time (minutes)			
Homeward Trips	31.96	34.75	31.51
Work Trips*	34.08	37.79	33.38
School Trips	25.91	27.85	25.74
Non-work Trips	30.27	35.28	29.28
All Trips	31.36	35.20	30.72
Average Travel Distance (km)			
Homeward Trips	2.67	3.03	2.61
Work Trips*	3.10	3.72	2.99
School Trips	1.95	2.24	1.92
Non-work Trips	2.69	3.42	2.55
All Trips	2.69	3.25	2.60

*includes self-employment trips

The highest percentage of trips are made for <=0.50 km. A sudden increase in share of trips is noticeable for distance >6.50 km for both major destinations and destinations other than major destinations, though the share is higher for major destinations **(Table 5.3)**.

Table 5.3: Percentage of Trips by Travel Distance and Destinations

Travel Distance (km)	All Destinations	Major Destinations	Destinations other than the Major Destinations
<= 0.50	31.6%	27.7%	32.2%
0.50 – 1.50	11.1%	2.6%	12.5%
1.50 – 2.50	14.6%	13.9%	14.8%
2.50 – 3.50	11.7%	14.9%	11.2%
3.50 – 4.50	8.8%	10.9%	8.4%
4.50 – 5.50	6.8%	9.0%	6.4%
5.50 – 6.50	4.4%	6.2%	4.1%
> 6.50	11.0%	14.7%	10.4%

Share of trips decreases with increasing travel time**.** Majority of the trips are made for up to 30 minutes of travel time. For major destinations, however, a good percentage of trips are made up to an hour of travel time. Trips made for more than 90 minutes is particularly low, especially to destinations other than the major destinations **(Table 5.4 and Figure 5.1)**.

Table 5.4: Percentage of Trips by Travel Time and Destinations

Travel Time (minutes)	All Destinations	Major Destinations	Destinations other than the Major Destinations
<= 30	59.3%	50.5%	60.8%
30 - 60	29.4%	34.7%	28.5%
60 - 90	9.5%	12.5%	9.0%
> 90	1.7%	2.3%	1.7%

Nearly one-fifth of the work trips to major destinations are made for up to 90 minutes of travel. For school trips, more than two-third of them are made for up to 30 minutes **(Figure 5.1)**. (See Appendix B for more detail)

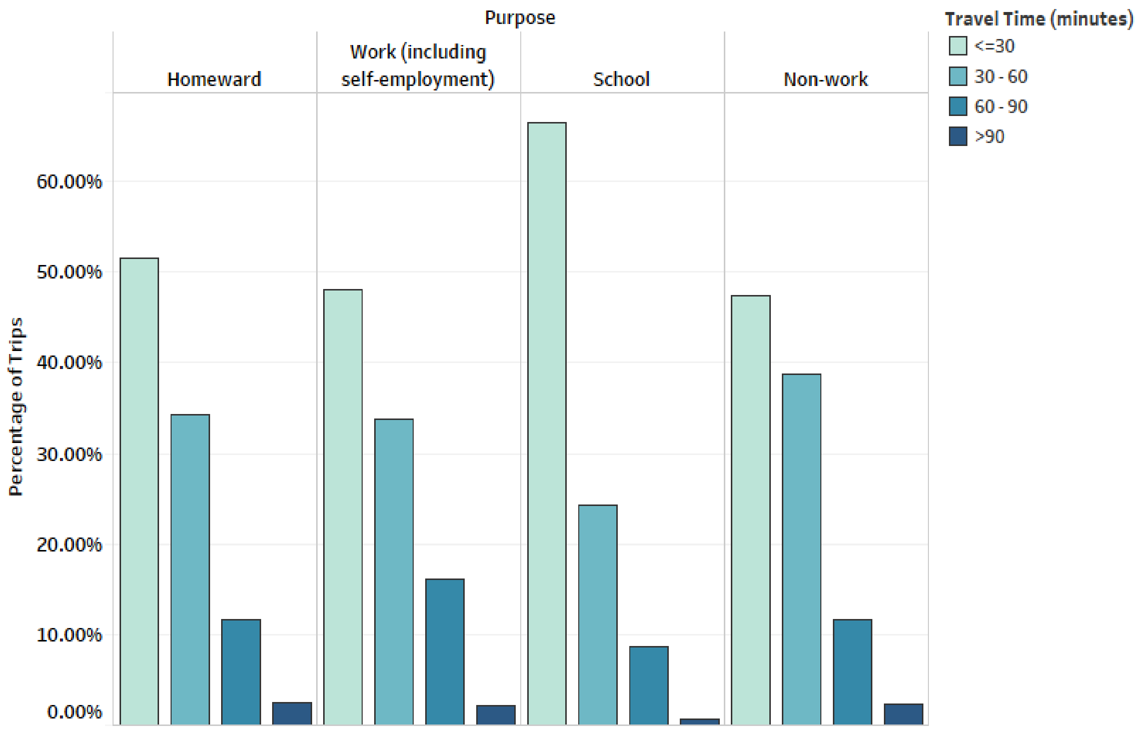

Figure 5.1: Distribution of trips to major destinations by purpose and travel time

Table 5.5: Modal Share of Trips by Destinations

Travel Mode	All Destinations	Major Destinations	Destinations other than the Major Destinations
Walking/Bicycle	22.2%	18.9%	22.7%
Rickshaw	44.8%	36.5%	46.2%
Motorcycle	1.6%	1.9%	1.6%
CNG/Mishuk/Taxi/Auto Tempo	5.3%	7.4%	5.0%
Car/Microbus/Jeep	3.5%	5.2%	3.2%
School/College Bus/Van	11.8%	14.7%	11.4%
Public Bus	10.6%	15.3%	9.9%
Others	0.1%	0.1%	0.1%

Walking/bicycle and rickshaw consist of a substantial modal share for all trip destinations **(Table 5.5)**. Compared to other destinations, modal share of walking/bicycle and rickshaw is noticeably lower for major destinations. Since trips made to major destinations are on an average involve longer travel time and distance compared to other destinations **(Table 5.2)**, lesser use of walking and non-motorized transport modes is expected. Yet, it is clearly evident that walking and non-motorized transport modes play a vital role in all trips made in the city.

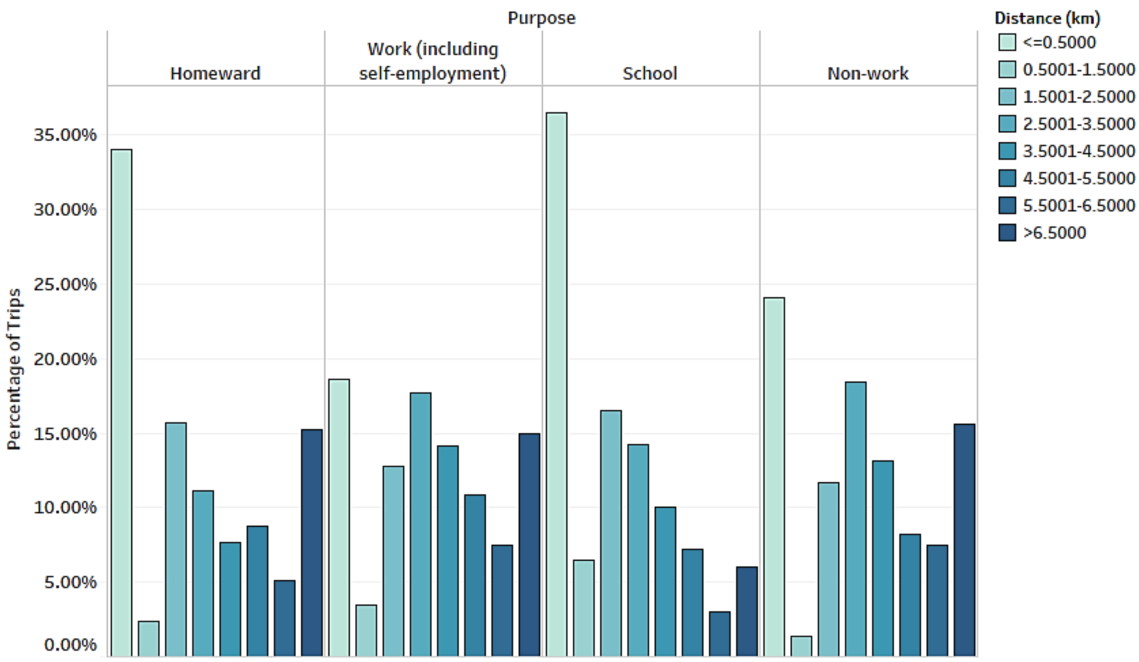

Figure 5.2: Distribution of trips to major destinations by purpose and distance

On an average, people travel for longer distances and time for work trips compared to other trips **(Table 5.2)**. Work trips to major destinations involve both more car and bus trips and lesser non-motorized trips **(Figure 5.3)**. School trips are generally shorter ones. School trips made to major destinations typically involve <=0.5 km and consistent with that, use of non-motorized modes are the highest for school trips **(Figure 5.2 and 5.3)**. (See Appendix B for more detail)

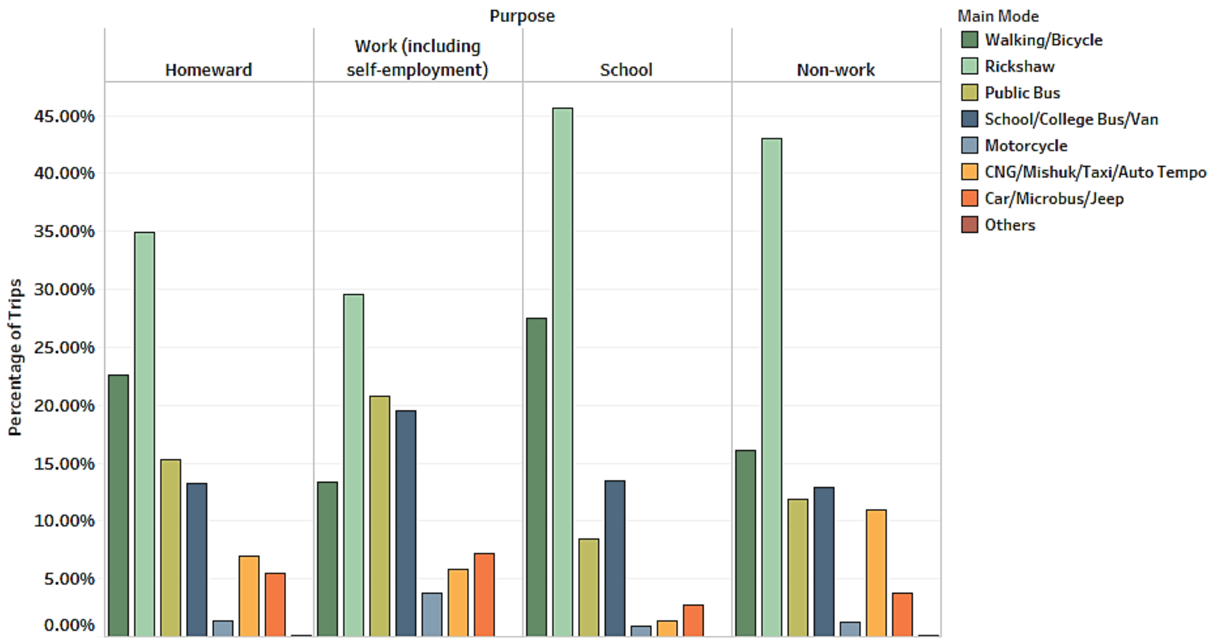

Figure 5.3: Distribution of trips to major destinations by purpose and main mode

Most of the trips made by walking/bicycle are made for up to distance of <=0.5 km. This indicates that the city dwellers rely heavily on non-motorized modes for short travel distances. People tend to travel for longer distances by both car and public bus. The importance of para-transit in the city can hardly be denied especially for longer distances. The share of CNG/mishuk/auto-tempo to major destinations is particularly noticeable for trip distances >3.5 km. However, these modes remain largely out of proper planning and focus in the city. This is an area for further research and planning.

Use of school bus/van trips increase steadily with increasing distance. Share of school bus/van trips to major destinations is noticeably high for trips >3.5 km reflecting the significance of institutional transport system. (See Appendix B for more detail)

Walking/bicycle dominates trips to major destinations for up to 30 minutes of travel. The share of rickshaw for up to 60 minutes of travel time is particularly visible **(Figure 5.4)**. Given that rickshaws are chosen modes for a large proportion of trips up to an hour of travel points to the fact that instead of excluding or disregarding them, Dhaka's transportation sector needs to effectively incorporate them. Share of bus increases steadily with increasing travel time. Similar thing can be said for car trips up to 90 minutes of travel. After that point, share of car lowers down. (See Appendix B for more detail)

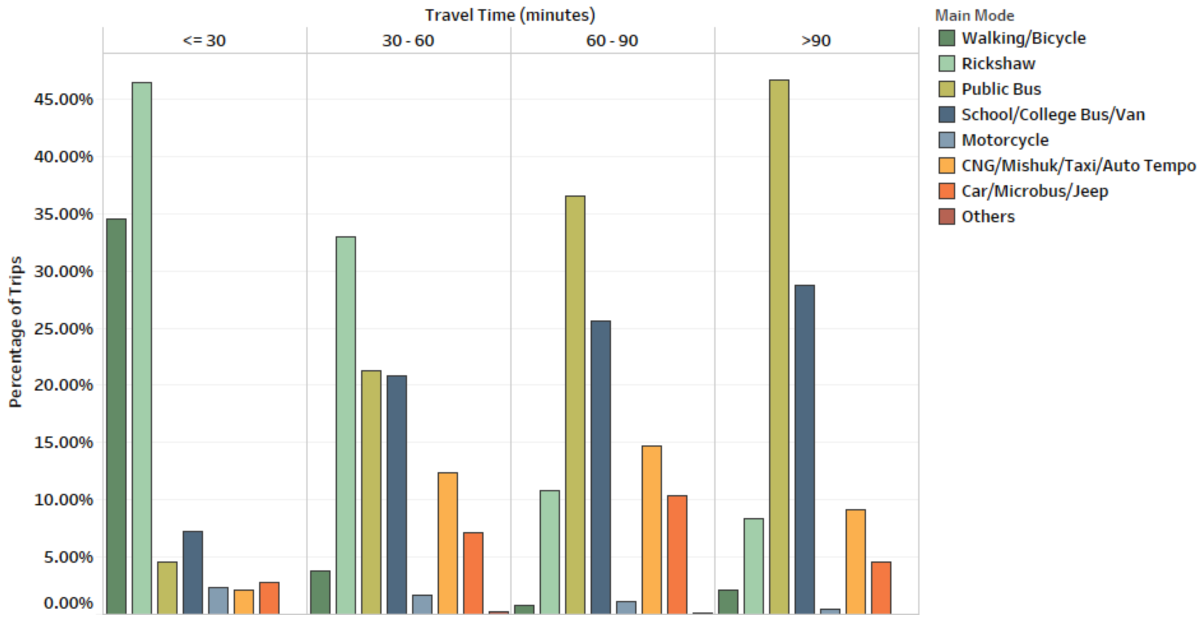

Figure 5.4: Distribution of trips to major destinations by travel time and main mode

5.3 TRAVEL BEHAVIOR MODELS AND RESULTS

The models explored here has estimated mode choice and household car ownership as a function of socio-demographic, built environment and attitudinal characteristics. Based on existing literature and the available database, a wide array of socio-demographic, travel, and built environment variables have been employed for the models. Literature review suggests that socio-economic and demographic and travel attributes of individuals and households play an important role in mode choice and car ownership decisions (Kockelman, 1997; B. Sun et al., 2017; Zhang, 2004). Therefore, although the focus of this research is to estimate the effects of accessibility on travel behavior in Dhaka, several socio-economic and demographic, built environment, and travel characteristics related variables have also been included. The use of a wide array of variables is expected to help in better understanding the extent to which accessibility influences travel behavior in Dhaka.

Thus, the explanatory variables can be categorized into four groups: (1) personal and household characteristics, (2) trip characteristics, (3) attitudinal characteristics, and (4) built environment characteristics. A summary of the explanatory variables used in the mode choice modeling is given below:

1. Personal and household characteristics:

- Age: Age of the trip-maker in years.
- Gender: Gender of the trip-maker (Male=1, otherwise 0)
- HH size: Total number of household members.
- HH composition: Four category was used: No child or elderly, Child but no elderly, elderly but no child, both child and elderly. No child or elderly was treated as the base.
- Children: No. of household members below 17 years defined as members below school-going age.
- Elderly: No. of household members above 59 years defined as members above retirement age in government jobs in Bangladesh.
- Female: No. of female members in the household
- Male: No. of male members in the household
- Working: No. of household members who are full-time or part-time employed.
- Income: Monthly income of the trip-maker in Bangladeshi Taka (BDT). 1 US$=84.48 BDT.
- HH income: Monthly household income in BDT.
- Income per member: Monthly household income divided by household size.
- License: If the trip-maker holds a driver's license (Yes=1, otherwise 0).
- Education: Educational level of the trip-maker categorized into illiterate, primary school, secondary school, higher secondary school, graduation, post-graduation and technical. Illiterate was considered as the base.
- Employed: If the trip-maker is full-time or part-time employed (Yes=1, otherwise 0).
- Car ownership: If the household owns a car (Yes=1, otherwise 0).
- Motorcycle ownership: If the household owns a motorcycle (Yes=1, otherwise 0).
- HH head's income: Monthly income of the household head in BDT.
- HH head's age: Age of the household head in years.

2. Trip characteristics:

- Travel Time: Travel time between trip origin and destination in minutes.
- Travel Distance: Network travel distance between trip origin and destination TAZ in kilometers. Due to unavailability of information to geocode the origins and destinations, TAZ centroids were considered here.

3. Attitudinal characteristics:

- Public transport safety: If the household head thinks that public transport is unsafe (Yes=1, otherwise 0).

4. Built environment characteristics:

- Accessibility: Accessibility was estimated using a cumulative opportunity-based metric as outlined in Chapter 4.
- Modal Accessibility Gap (MAG): MAG calculated as outlined in Chapter 4
- Population density: Population density at TAZ level calculated as Total population/Total area (per km^2).
- Job density: Job density at TAZ level calculated as Total persons engaged/Total area (per km^2).
- Entropy: Calculated at TAZ level as, $-\sum_j [P_j \ln(P_j)]/\ln(J)$ where P_j is the proportion of developed land in the jth use in the TAZ and J is the number of land use categories considered (Zhang, 2004). It is based on developed area entropy and computed at 100 meter grid cell. Here J=5: residential, commercial and industrial, mixed use, community, health and educational facilities, administrative and institutional use.
- Dissimilarity index: Calculated at TAZ level as $\sum_k \frac{1}{k} \sum_i^8 \frac{X_{ik}}{8}$ where k is the number of developed grid cells and X_{ik} is 1 if the central grid's land use differs from that of a neighboring grid and 0 otherwise (Kockelman, 1997). The same 5 land use categories were used.
- Nearest bus stop: Network distance from TAZ centroid to the nearest bus stoppage (km).
- Road density: Calculated at TAZ level as Total road area/Total area.
- Connectivity: Defined as % 3-leg intersections, % 4-leg intersections, % Connected nodes (non-dead end nodes) in the TAZ.

5.3.1 Modeling Mode Choice Decision to Major Destinations

Model Specification

Mode choice decision represents a categorical variable. A discrete choice binary logistic regression model was used to estimate the effects of built environment factors on mode choice between car and public bus. Two models have been presented for both work and non-work trips- the base model include only the socio-economic and demographic characteristics of the trip-makers. The expanded model include the built environment characteristics measured at the TAZs of trip origins and destinations. An incremental variable addition and deletion approach was employed and only the variables that increased the model goodness-of-fit were retained in the final model specifications. The goodness-of-fit the models were ascertained by likelihood ratio test and pseudo R^2 statistics (as measured by Nagelkerke R^2 and Hosmer and Lemeshow Test).

DHUTS HIS database contains attitudinal information of the household heads only. In the existing socio-cultural and economic context of Bangladesh, oldest or highest income earning male members are usually considered as household heads. Their perception about travel would not realistically represent the perception of women or family members of other age groups and might potentially provide a misleading and incomplete picture. Therefore, although several studies indicate the role of attitudes in influencing travel behavior, attitudinal information could not be incorporated in this model (Kitamura et al., 1997; Shen et al., 2016).

Descriptive Statistics

From the original dataset, work and non-work trips made to the major destinations by car and public bus were extracted. After accounting for inconsistent or missing data, this final dataset contained 1,154 trips of which 704 were work trips and 450 were non-work trips. Non-work trip purposes include shopping, social, recreation, medical, religious, etc. Among the trips in the final sample, 76.5% were made by bus and 23.5% by car.

Table 5.6: Summary Statistics of Variables in Mode Choice Modeling

Variables	Mean	S.D.
Trip-maker's personal and household characteristics		
Age (years)	38	12
Monthly income (BDT)	22,742	29,809
Monthly household income (BDT)	43,909	42,968
Household size	3.8	1.2
No. of children in the household	0.97	0.94
No. of elderly in the household	0.21	0.47
No. of female members in the household	1.9	0.9

No. of male members in the household	2.13	0.9
No. of licensed drivers in the household	0.24	0.5
No. of working members in the household	1.5	0.7
No. of cars owned by the household	0.18	0.42
Trip characteristics		
Travel time (minutes)	51.9	24.7
Travel distance (km)	5.4	2.7
Built environment characteristics		
Distance to the nearest bus stoppage (km)	1.09	0.59
Road density	0.14	0.06
Entropy	0.59	0.16
Dissimilarity index	0.26	0.11
Population density (per sq. km.)	73,517	33,184
Job density (per sq. km.)	28,011	32,443
% 3-leg intersections	49.24	9.43
% 4-leg intersections	8.71	4.95
Connected node ratio (%)	83.14	7.65
Accessibility (walk-bus, 30 minutes)	14,279.42	23,846.13
Accessibility (car, 30 minutes)	132,120.72	98,056.15
Accessibility (walk-bus, 45 minutes)	25,340.38	33,680.35
Accessibility (car, 45 minutes)	215,600.09	101,394.74
Accessibility (walk-bus, 60 minutes)	40,869.35	46,343.43
Accessibility (car, 60 minutes)	288,139.91	78,678.48

Model Estimation Results and Discussion

The binary logistic model estimation results and discussion showing the likelihood of an individual choosing car over bus for work and non-work trips are presented in this section **(Table 5.7 and 5.8 respectively)**.

<u>Work Model</u>

Personal and Household Characteristics

Socio-economic and demographic characteristics of the individual and their household play a dominant role in mode choice decisions, with the expected effects of income and car ownership. The effect of car ownership is particularly prominent. Having a driver's license also significantly influence car mode choice.

Relationship between gender and mode choice has been found to differ across previous studies. Whereas some studies found that women are more likely to use cars, some studies have also found the opposite (Robert Cervero, 2002; Etminani-Ghasrodashti & Ardeshiri, 2016; Ma et al., 2015; Shen et al., 2016). This study has found that compared to males, females are more likely to use a car. In our context, a reason of women using car more compared to men can be that women are more likely to make complex trip chains involving work and various non-work trips e.g. grocery shopping, childcare, etc. which are very difficult to carry out using public bus (Robert Cervero, 2002).

Another reason might be the ever-growing safety issues for women associated with travelling by public transport in Dhaka. Although women's complex trip chains have been studied extensively, effect of safety issues on their travel behavior has not received much attention in related studies.

Household size exerts a negative effect on car mode choice. This is probably due to the fact that majority of the car-owning households own only one car here and many people might choose to keep that car dedicated for their children's school trips instead of using them for their own work trips. Another likely reason could be that car ownership comes with a considerable amount of operation and maintenance costs (e.g. fuel costs, insurance costs, driver's salary, etc.). An increasing household size might mean increasing budgetary constraints and decreasing discretionary income which might affect the mode choice.

Built Environment Characteristics

In spite of the dominant role of socio-economic and demographic factors, inclusion of the built environment variables improved the goodness-of-fit of the model (as indicated by both likelihood ratio test and pseudo R^2 statistics). Consistent with our general understanding, increased population density at origin is statistically significantly associated with less likelihood of traveling by car. Increased distance to the nearest bus stoppage at origin exerts positive influence on car mode choice. This is expected given the increased time and physical labor involved with increasing walking distance to the bus stoppages.

Table 5.7: Discrete Choice Model Estimates of Car Mode Choice for Work Trips

	Base			Expanded		
Variables	**Coef.**	**S.E.**	**Exp (B)**	**Coef.**	**S.E.**	**Exp (B)**
Constant	-2.161	0.600	0.115	8.704	3.210	6026.713
Trip-maker's personal and household characteristics						
Age	0.024*	0.013	1.025	0.025*	0.014	1.025
Gender	-1.570***	0.448	0.208	-1.605***	0.460	0.201
Licensed driver	2.963***	0.320	19.347	3.001***	0.332	20.111
Monthly income (Tk.1000)	0.017***	0.006	1.017	0.015*	0.006	1.015
Household size squared	-0.023	0.015	0.977	-0.027*	0.016	0.973
Car ownership	3.687***	0.426	39.917	3.711***	0.438	40.892
Built environment characteristics						
Ln (Population density at origin)	-	-	-	-0.785***	0.279	0.456
Ln (Job density at origin)	-	-	-	-0.185	0.213	0.831
Distance to nearest bus stop at origin	-	-	-	0.534**	0.268	0.586
Ln (Entropy at destination)	-	-	-	-0.287	0.420	0.751
Z (Accessibility (walk-bus, 60 minutes))	-	-	-	-0.276*	0.142	0.759
Mode output statistics						
-2 log-likelihood at initial	769.028			769.028		
-2 log-likelihood at final	396.071			379.802		
Nagelkerke R squared	0.619			0.639		
Model improvement test (-2LL$_{Basemodel}$ – (-2LL$_{Expandedmodel}$))	$\chi2$ = 16.269, df= 5					

N=704; Indicated by estimate with level of significance (* < 0.1, ** < 0.05, *** < 0.01)

Table 5.8: Discrete Choice Model Estimates of Car Mode Choice for Non-work Trips

	Base			Expanded		
Variables	**Coef.**	**S.E.**	**Exp (B)**	**Coef.**	**S.E.**	**Exp (B)**
Constant	-23.072***	3.142	0.000	-15.185***	4.234	0.000
Trip-maker's personal and household characteristics						
Age	0.045**	0.015	1.046	0.044**	0.016	1.044
Gender	-1.248**	0.410	0.287	-1.378**	0.476	0.252
Licensed driver	1.781**	0.722	5.938	2.022**	0.775	7.552
Ln (Household income)	2.207***	0.309	7.590	2.122***	0.327	8.345
Household size	-0.529**	0.178	0.589	-0.524**	0.179	0.592
Car ownership	3.511***	0.484	33.473	3.999***	0.556	54.549
Built environment characteristics						
Ln (Job density at origin)	-	-	-	-0.508*	0.286	0.602
Distance to nearest bus stop at origin	-	-	-	0.410	0.748	1.506
Ln (Entropy at destination)	-	-	-	-1.366*	0.810	0.255
Z (Accessibility (walk-bus, 45 minutes))	-	-	-	0.602**	0.219	1.825
% 3-leg intersections at origin	-	-	-	-0.027	0.024	0.973
% 3-leg intersections at destination	-	-	-	-0.082*	0.042	0.921
Mode output statistics						
-2 log-likelihood at initial	486.554			486.554		
-2 log-likelihood at final	199.547			180.774		
Nagelkerke R squared	0.714			0.746		
Model improvement test ($-2LL_{Basemodel}$ – ($-2LL_{Expandedmodel}$))	$\chi2$ =18.773, df= 6					

N=450; Indicated by estimate with level of significance (* < 0.1, ** < 0.05, *** < 0.01)

Increase in multimodal accessibility has also demonstrated statistical relevance in decreasing car mode choice. This is an important finding in this study since it depicts that potential measure (or accessibility) actually influences realized travel behavior in Dhaka.

Non-work Model

Personal and Household Characteristics

The parameter estimates of personal and household characteristics show effects and signs in the non-work model similar to the work model. Therefore, those details are not being repeated in this section.

Built Environment Characteristics

Built environment variables play an important role in non-work mode choice model as well. Increasing distance to the nearest bus stoppage at origin is associated with the likelihood of using a car which is expected. An increased distance to bus stoppage is linked with complexity in performing non-work trips e.g. carrying shopping bags, accompanying children, traveling for medical purposes, etc. Also non-work trips involve more off-peak hour trips compared to work trips and bus service is usually less frequent during those hours relative to commuting hours.

Increasing destination entropy leads to less likelihood of choosing a car. This is similar to our overall understanding that mixed land uses discourage car use by making different opportunities closer by.

Accessibility shows an opposite sign from our expectation. Although such outcomes are not uncommon in related studies (Kockelman, 1997; Ye & Titheridge, 2017). In this study, increase in both car and bus accessibility showed an increase in the likelihood of car mode choice (The model with bus accessibility has been chosen because that improves the overall model-fit). This may seem counterintuitive at first. However, accessibility by car and bus more often than not increases (or decreases) simultaneously- just at a different magnitude. An increase in accessibility indicates that opportunities are closer- by both car and bus. But that do not necessarily reflect the level-of-service in a comprehensive manner. For example- in this study, factors like bus frequency, availability, reliability, etc. could not be incorporated because of lack of data and absence of any specific transit schedule in the city (Victoria Transport Policy Institute, 2019, 21 March). However, these play important roles regarding attitudes towards public transport and attitudes can influence travel behavior (Kitamura et al., 1997). As stated earlier, such issues are even more crucial when non-work trips are made because of lack of transit services during off-peak hours and complexity in carrying out such trips by public bus.

Another possible explanation might be the effect of residential self-selection i.e. people living in the more accessible locations do not necessarily depend on public transport for non-work trips. Whereas investigating residential self-selection is not within the scope of this study, there is future scope of exploring this issue in the context of Dhaka.

No trip characteristics related variables were found to be influential in either of the mode choice models.

5.3.2 Modeling Household Car Ownership Decision

Model Specification

Data of a total of 3,050 households have been used for car ownership modeling. Among the sample households, around 7% owns car with majority of them owning just one car (less than 0.5% households own more than one car). Therefore, a binary logistic model has been used to examine the effects of household and built environment characteristics on household’s car ownership decision. Here, it is to be noted that unlike many developed countries, in our country’s context, car is considered a family resource and not an individual resource. Therefore, the household head’s attitude towards public transport might play a role here and so, attitudinal information has been included modeling car ownership decision.

Similar to mode choice models, one base and one expanded model have been developed here. The goodness-of-fit the models were ascertained by likelihood ratio test and pseudo R^2 statistics (as measured by Nagelkerke R^2 and Hosmer and Lemeshow Test).

Descriptive Statistics

Since car ownership is not an individual resource in the country’s context, only variables applicable at household level and related to the household head have been used here. Built environment variables have been estimated at home TAZ of the households.

Table 5.9: Summary Statistics of Variables in Car Ownership Modeling

Variables	Mean	S.D.
Household and attitudinal characteristics		
Monthly household income (BDT)	38,304	39,110
Household size	3.66	1.2
No. of children in the household	1.03	0.92
No. of elderly in the household	0.18	0.43
No. of female members in the household	1.83	0.89
No. of male members in the household	2.07	0.91
No. of licensed drivers in the household	0.18	0.45
No. of working members in the household	1.38	0.71
No. of motorcycles owned by the household	0.05	0.22
Age of the household head (years)	41.61	10.63
Income of the household head (BDT)	32,298	34,903
Built environment characteristics		
Distance to the nearest bus stoppage (km)	1.14	0.56
Road density	0.14	0.06
Entropy	0.58	0.15
Dissimilarity index	0.27	0.10
Population density (per sq. km.)	75,908	32,221
Job density (per sq. km.)	32,432	41,179
% 3-leg intersections	48.91	8.64
% 4-leg intersections	8.44	4.56
Connected node ratio	83.49	8.27
MAG (morning peak, 60 minutes)	0.81	0.23
MAG (off-peak, 60 minutes)	0.82	0.18
MAG (evening peak, 60 minutes)	0.79	0.19

Table 5.10: Discrete Choice Model Estimates of Household Car Ownership

	Base			Expanded		
Variables	**Coef.**	**S.E.**	**Exp (B)**	**Coef.**	**S.E.**	**Exp (B)**
Constant	-5.191***	0.398	0.006	-10.681***	1.450	0.000
Household characteristics						
HH income (Tk.1000)	0.015***	0.002	1.015	0.016***	0.002	1.016
No. of workers in the HH	-0.215*	0.121	0.806	-0.235*	0.122	0.790
No. of licensed drivers in the HH	1.712***	0.135	5.541	1.751***	0.136	5.760
Age of HH head	0.032***	0.008	1.033	0.031***	0.008	1.032
Motorcycle ownership	-0.981**	0.390	0.375	-1.005**	0.396	0.366
Attitudinal characteristics						
Problem: public transport is unsafe	0.222	0.216	1.249	0.211	0.218	1.234
Built environment characteristics						
Road density	-	-	-	4.976***	1.209	144.917
Modal accessibility gap (morning peak, 60 minutes)	-	-	-	1.675**	0.494	5.340
Ln (Job density)	-	-	-	0.345**	0.105	1.412
Mode output statistics	-	-	-			
-2 log-likelihood at initial	1493.551			1492.313		
-2 log-likelihood at final	1109.519			1077.571		
Nagelkerke R squared	0.305			0.329		
Model improvement test ($-2LL_{Basemodel} - (-2LL_{Expandedmodel})$)	$\chi 2 = 31.948$, df = 3					

N=3050; Indicated by estimate with level of significance (* < 0.1, ** < 0.05, *** < 0.01)

Model Estimation Results and Discussion

The binary logistic model estimation results and discussion showing the likelihood of a household owning a car is presented in this section **(Table 5.10)**.

Household and Attitudinal Characteristics

Household characteristics play a crucial role in car ownership decisions. Household income is positively associated with car ownership which is expected. Increasing income allows a household to buy and maintain the expenses of having a car. As the number of licensed drivers increases, a household becomes more likely to have a car. This might be associated with the potential of avoiding the expenses associated with employing a driver. This variable, however, may be related in a different way as well i.e. once a household owns a car, the household members are more likely to avail driver's license.

Older heads are more likely to own a car in their households. This is possibly due to having a more stable job and income with increasing age. Unlike our general perception, the number of workers negatively affects car ownership. This might be because owning a car does not provide sufficient utility when there are many working members in the household. While it is possible to have work trip chaining for two members, it is typically quite complex to chain work trips for more than two members. In such cases, the other working members are likely to depend on other modes. Therefore, the operation and maintenance costs of the car may overwrite the overall advantages of having a car and produce disutility for the household.

Having a motorcycle in the household negatively affects car ownership. This indicates that motorcycle plays as an alternative mobility tool for households, at least to some extent.

Among the attitudinal variables, it was found that a household is more likely to have a car if the household head feels that public transport is unsafe. This reveals that the household head's perception indeed affect car ownership decisions, at least to a certain degree.

Built Environment Characteristics

Built environment variables have been found to be improving the model indicating their strong influence in car ownership decisions. Increased road density in the TAZ of a household increases the likelihood of car ownership. Increased road density possibly encourages easier and faster movement of a car. This is an important finding since a school in the country advocates for increasing roadways in Dhaka as a means of reducing traffic congestion. However, the findings here suggest that increasing roadways is more likely to result in more car ownership and a subsequent consequence of even more congestion.

Increased job density in the TAZ is associated with increasing car ownership. This might be because as there becomes more jobs available within the household's TAZ, people tend to avail those jobs and a car is better suited than public bus or para-transit modes to reach them.

Increasing modal accessibility gap increases the likelihood of car ownership i.e. as public transit accessibility lowers compared to car accessibility in the TAZ, households tend to own a car. From policy perspective, this is a vital outcome since this indicates that improving public transport accessibility could potentially contribute in minimizing car ownership.

5.4 CONCLUSION AND POLICY IMPLICATIONS

5.4.1 Built Environment and Travel Behavior

Do built environment variables influence mode choice and car ownership decisions in Dhaka? In short, the answer is "Yes". Would measures bringing changes in built environment factors be adequate to influence those decisions? - "No." At least from this study, sufficient evidence could not be found to exclusively focus on land use characteristics to alter travel behavior. Built environment characteristics albeit play an important role and all the models show explicit improvement after including those variables. The study found statistically significant effect of several built environment variables e.g. accessibility, entropy, connectivity, road and job density, etc. Yet, the overwhelming influence of income, car ownership and having a driver's license can hardly be ignored. Simply putting, people tend to buy car as soon as they can afford to buy one and tend to use car as soon as they buy one.

Findings from the models suggest that policies and planning initiatives aimed for sustainable development to be successful, strategies like enhancing public transport accessibility or promoting mixed use development need to be supplemented with mobility-limiting strategies. A number of such strategies have been implemented worldwide (S. L. Handy, 2002). Compared to highly automobile-dependent societies, mobility-limiting strategies may prove to be beneficial in Dhaka since still only a small segment of people depend on cars. Therefore, unlike the auto-dependent developed countries, congestion pricing, parking pricing, etc. are less likely to disproportionately affect low-income population here. Siddique and Choudhury (2017) found congestion pricing to be a promising strategy for Dhaka. High parking charges in the major destination TAZs, congestion pricing during peak hours to the major destinations, etc. can be some of the potential alternatives. Increasing import duty fees on cars could also be an option. Nevertheless, none of these strategies should be implemented without adequate studies since limiting mobility without enhancing accessibility, mixed land use or transit-oriented development might not always work as expected. Even if they work, they work at the expense of marginalized segment of population being disproportionately affected.

5.4.2 Accessibility and Travel Behavior

Exploring the effect of accessibility on travel behavior has been a key focus of this study. Recalling the two facets of the research motivation from Chapter 1, there is a latent need to understand the effects of *potential travel behavior* (which is accessibility) on actual travel behavior and if accessibility has any effect on actual travel behavior, it has important policy implications. Again, recalling from Chapter 2, urban planners and policymakers have far more influence on built environment attributes compared to individual and household characteristics. Although several personal and household attributes as well as built environment ones have been found to be statistically significant in the models described above, accessibility is one built environment variable that has retained statistical relevance in all three models.

These illustrate that planners and policymakers need to carefully consider the importance of accessibility in reducing car ownership and use. The study findings have showed that increasing road density to reduce traffic congestion is not an effective solution for the city since it encourages car ownership for faster, easier travel. Rather planners and policymakers should focus on connecting people to opportunities through sustainable means or in other word, enhancing public transport accessibility.

Improving public transport accessibility could take a number of forms which are interdependent on each other. New infrastructure investments should take into account how the major destinations could be well-served across the day. Any infrastructure investment should carefully consider whether that is connecting people to the opportunities they want to avail. Since the major destinations are the locations forming a cluster of high number of trips attracted, improving public transport accessibility to these locations could be a promising and investment-worthy option to reduce overall car use in the city.

Again, improving public transport accessibility does not only have to be infrastructure-dependent. Public transport accessibility could be improved through soft measures as well i.e. by improving service quality. Public transport service should take into account off-peak hours as well to minimize car dependence for non-work trips. Not only reliable and affordable service but also comfortable and safe service is required. This again needs to be supplemented with reliable and effective public transport scheduling and supply of and access to required feeder modes.

The majority of the people still depend on public transport and non-motorized transport in Dhaka. At the same time, added private cars on streets only lead to increased congestion and reduced overall accessibility. Together these two give sufficient reasons to invest in multimodal public transit services and limit car-based mobility.

5.4.3 Concluding Remarks

Attitudinal information could not be incorporated in the mode choice models in this study. Future research should attempt to address this limitation. This research may further be used to explore residential self-selection in Dhaka. Another direction that this research may take is to explore the potential of different accessibility-enhancing and mobility-limiting strategies here.

This study, however, examined a wide array of variables to explore the effects of built environment and particularly accessibility on travel behavior in the context of Dhaka. The major destinations by time-of-day approach taken in this research specifically identifies where potential future investments should be made for a greater benefit of the society. This study also reveals that built environment factors alone will not be able to bring any drastic change in mode choice behavior unless car ownership and use are explicitly discouraged. However, it has to be remembered that any mobility-limiting strategy needs to be implemented only after adequate research so that it does not affect people disproportionately in any way. Moreover, no matter how much strict mobility-limiting strategy is undertaken, there would be people who could afford and maintain private automobiles. And given that people's disposable income is increasing over time, the number of such people is likely to increase as well. Therefore, accessibility-enhancing strategies are equally important. The workaround is to make public transport attractive to people- by making it safe, reliable, accessible and ensuring that it enables people reach the opportunities they want and is worth their time and money.

Chapter 6

Synthesis of Research Findings and Policy Implications of Accessibility and Travel Behavior

6.1 INTRODUCTION

Over the years, a number of transportation policy and planning documents have been drafted to meet the latest challenges in the transportation sector of Dhaka. Some of these documents have been aimed solely at transportation sector while some others encompassed all relevant sectors to provide a holistic guideline for the city's planning process. Some of these documents also drew direct motivation from the limitations or recommendations of some previous planning documents.

Chapter 4 has demonstrated that there is significant accessibility gap between private car and multimodal public bus and public bus users stay at a considerably disadvantageous position throughout the day compared to car users more due to the mode they use and less due to their location of residence. In chapter 5, it was found that accessibility has statistically significant effect on mode choice and car ownership decisions i.e. improving public bus accessibility could potentially reduce car ownership and use. This takes us back to the conceptual underpinnings from our introductory chapter: *potential* measures (or accessibility) has been found to affect realized travel behavior. Therefore, there exists a solid basis to evaluate the extent to which accessibility and travel behavior have been meaningfully integrated in the policy and planning documents since the study findings confirm that accessibility could be a powerful tool to influence travel behavior.

The aim of this chapter is to synthesize the travel behavior and accessibility patterns analyzed in the previous chapters with the goals, objectives and strategies outlined in those planning documents. It would be attempted to critically evaluate how meaningfully accessibility has been incorporated in the relevant planning documents of Dhaka. In doing so, guidelines would be provided on how travel behavior and multimodal accessibility could be effectively and comprehensively incorporated in the planning process and practices.

6.2 RESEARCH FRAMEWORK AND METHODOLOGY

The five most relevant and widely cited policy and planning documents have been reviewed. These documents have been considered as guideline for urban transportation planning for the city. Documents like Strategic Transport Plan (STP) for Dhaka, 2005 received status of official transportation framework as well (Japan International Cooperation Agency & Dhaka Transport Coordination Authority, 2015). To conceptualize its policies, Dhaka Urban Transport Network Development Study (DHUTS) in Bangladesh, 2010 was undertaken and later on, Revised Strategic Transport Plan (RSTP) for Dhaka, 2015 came into being to cater the demand of changing time. The documents reviewed are as follows:

1. Strategic Transport Plan (STP) for Dhaka, 2005
2. Dhaka Urban Transport Network Development Study (DHUTS) in Bangladesh, 2010
3. National Integrated Multi-modal Transport Policy (NIMTP), 2013
4. Revised Strategic Transport Plan (RSTP) for Dhaka, 2015
5. Draft Dhaka Structure Plan (2016-2035)

These policy and planning documents do not necessarily encompass the same scale of geography as the study area of this research. However, all of them have components that is relevant to the analysis and any component that is outside of the study area has been carefully excluded from the analysis.

Here, it is to be noted that, the concept of 'multimodality' in NIMTP is slightly different from the definition used in this study. By multimodality, NIMTP focuses on integration of various modes in the overall transportation system network. The author acknowledges this difference and therefore, limit the analysis of NIMTP to the broad objectives and investment criteria outlined. Yet, it has been included because NIMTP presents some noteworthy sketches of objectives and investment criteria related to accessibility which could still be a guideline.

To achieve the goal of this chapter, the following research questions would be answered:

- To what degree multimodal accessibility has been incorporated in the transportation plans of Dhaka over the years?
- What types of performance indicators have been used to translate accessibility related visions, policies and goals into specific objectives and strategies?
- To what extent the goals, objectives and strategies meaningfully reflect multimodal accessibility as the ease of reaching destinations and availing desired opportunities?

- To what extent the planning initiatives proposed in the transportation plans of Dhaka comply with the travel behavior and accessibility patterns identified in the study?

To answer the research questions, visions, policies, goals, objectives and strategies were selected from the documents that are related to accessibility either explicitly or implicitly. However, this is not a straight-forward process. Accessibility, mobility, connectivity, etc. are not isolated concepts. A measure oriented towards enhancing mobility may enhance accessibility as well and vice-versa. This is the reason several mobility-oriented objectives or strategies were also included as part of the synthesis process if they seemed to be linked with accessibility-oriented goals, objectives or strategies. In general, objectives or strategies aiming at increasing roadway capacity, reducing congestion, improving travel times or enhancing pedestrian or non-motorized movement without clear linkage between origin and destinations, etc. have been defined as mobility-oriented objectives or strategies. Accessibility-oriented objectives or strategies were defined as the ones aimed at reducing the need for travel, increasing ease of availing desired opportunities, improving clear linkage between origin and destination, focusing the need for disadvantaged or marginalized population by increasing travel options, land use strategies, etc. (S. Handy, 2005). They were then critically assessed to see how well they reflect the concept of accessibility and how meaningfully they have been translated into performance indicators or quantifiable measures.

A mixed content-structuring analysis (also known as ‘keyword in context’) was conducted to explore how accessibility has been included in the plans both explicitly and implicitly (Mayring, 2014). Qualitative data analysis software ATLAS.ti was used in this process. At first, the plans were carefully skimmed through to find out accessibility related vision, goals or objectives. A deductive summative content analysis approach was taken to explore how accessibility has been incorporated in the plans. Themes were deliberately focused as unit of count instead of just words because accessibility is often expressed through different conceptual ideas (Lune & Berg, 2016). Based on theory and literature review, some key themes were selected e.g. accessibility, access, accessible, reach, ease of reaching destinations, get to, link, etc. This step was crucial for the study to get a good understanding of the degree to which the concept of accessibility has been able to manifest itself in its core form in the planning documents. Unfortunately, for some plans, this step did not provide much useful information.

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Strategic Transport Plan (STP) for Dhaka, 2005	**Strategic Goal 2: Mobility and Accessibility** Provide a basic level of mobility and accessibility for all segments of society to ensure reasonable access to employment, education, health, social and other programs, services and opportunities.	Accessibility-oriented	None	Acknowledges walking as feeder mode, thereby indicating the importance of multimodality. Different groups of disadvantaged or marginalized population have been focused. Different work and non-work facilities have been considered.
	Sub-Goal 2A: Meet mobility requirements of all segments of society.	Accessibility-oriented	None	
	• Supply all areas with good transport services, Provide a basic level of transport services to the poorest people, Serve transportation needs of the disabled and handicapped, Provide good access to educational institutions and employment opportunities, Provide good access to educational institutions and employment opportunities, Provide alternative transportation modes and options within major travel corridors	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Strategic Transport Plan (STP) for Dhaka, 2005	• Emphasize schemes that make walking easier, less hazardous and less stressful, so that walking (as a complete trip, or as access to/from other modes of travel) becomes a preferred choice rather than a necessity	Mobility-oriented	None	
	Strategic Goal 7: Social Development	Both		
	Sub-Goal 7A: Develop affordable transport options for low income groups to provide access to additional employment opportunities and other services.	Accessibility-oriented	None	
	• Provide good transport services to areas with concentrations of low income groups.	Accessibility-oriented	None	
	• Provide good pedestrian facilities to encourage and facilitate walking.	Mobility-oriented	None	
	Sub-Goal 7D: Ensure that all transport services are suitable for use by all persons, particularly including women and selective societal groups (children, disabled, elderly, etc.).	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Dhaka Urban Transport Network Development Study (DHUTS) in Bangladesh, 2010	**Mission 2: Equitable of peoples mobility** The transport sector is generally responsive for assuring social equity, providing all people with equitable accessibility to places for their employments, school, commercial activities, social services, medical care, etc.	Accessibility-oriented	None	Different work and non-work facilities have been considered. Focus revolves around mobility in general. Accessibility related strategies remain vague.
	Strategy 1: Improvement of People's Mobility			
	• Introduction of Traffic Demand Management (TDM)	Mobility-oriented	None	
	Strategy 3: Safe and Secure Transport			
	• Priority to Pedestrian Traffic	Mobility-oriented	None	
	Strategy 4: Accessible Transport for All People			
	• Accessible transport for all the poor • Accessibility to new satellite community	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
National Integrated Multi-modal Transport Policy (NIMTP), 2013	**Objectives:** • Ensure that transport meets social needs – in terms of its cost and accessibility to all sectors of society • Reduce the need for travel by better land use planning	Accessibility-oriented	None	'Social inclusion' gives idea of mainstreaming disadvantaged groups of population. Different work and non-work facilities have been considered. Instead of only poor people, it specifically mentions about people without a car. Objectives are supported by investment criteria.
	Investment Criteria: • Accessibility - improving access to everyday facilities for the poor and those without a car and reducing community severance • Social inclusion – meeting the needs of women, the elderly and the disabled • Providing accessibility to basic health and education facilities.	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Revised Strategic Transport Plan (RSTP) for Dhaka, 2015	**Vision and Goal:** Ensure mobility and accessibility to urban services that are vital for the people and the society, by providing a transport system characterized by safety, amenity, and equity and sustained by an efficient public transport system.	Accessibility-oriented		No clear consideration of disadvantaged groups of population in objectives and strategies although the vision explicitly speaks about equity. Accessibility-oriented strategies are mostly vague.
	Objectives and Strategies:			
	B. Effective Management of Urban Growth and Development			
	Promotion of integrated urban and transport development, particularly Transit-Oriented Development (TOD)	Accessibility-oriented	None	
	C. Promotion and Development of Attractive Public Transport			
	Early introduction of an integrated public transport system in the effort to maintain public transport share, Promotion of public transport use and expansion of services, Providing an Affordable Public Transport system	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Revised Strategic Transport Plan (RSTP) for Dhaka, 2015	Exploitation of para-transit and NMVs	Mobility-oriented	None	
	E. Effective Transport Demand Management (TDM)			
	Integrating urban development and transport (TOD), Providing efficient public transport alternatives	Accessibility-oriented	None	
	Regulating motorized vehicle access and proper charging of road use and parking	Mobility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Draft Dhaka Structure Plan (2016-2035)	**Long Term Policy Framework: Transport for Efficient Connectivity**			Explicit focus on some innovative ideas e.g. staggered office hours and IT and several mobility-limiting strategies as well as reducing SOV use. 'Development that caters to the transit dependent population should be located on or within walking distance of a bus route.' is unclear and confusing given there is no explanation how some developments would cater only these people and why this is focused instead of their universal access.
	Goal: Safe, Affordable, Sustainable and Connected Communities			
	Objective 1: To Prepare Long Term Transport Network Plan			
	Policy 1.1: Enhancing the Linkage between Land Use and Transport Network			
	Implementation Tools:			
	Development that caters to the transit dependent population (e.g., elderly, disabled, or disadvantaged persons) should be located on or within walking distance of a bus route.	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Draft Dhaka Structure Plan (2016-2035)	**Policy 1.5: Encourage Development of Sidewalk and Bicycle Route for Both Mobility and Recreation Purposes**			
	Implementation Tools:			
	Provide pedestrian/cycle accessibility to neighboring facilities including, schools, shops, parks and recreation facilities, community facilities, bus stops, train stations etc.	Accessibility-oriented	None	
	Objective 2: To Make Public Transport Efficient and Sustainable			
	Policy 2.1: Introduction of Mass Rapid Transit (BRT and MRT)			
	Implementation Tools:			
	Promote Transit-Oriented Development (TOD) along BRT/MRT Stations in close cooperation with transport corridor and urban development	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Draft Dhaka Structure Plan (2016-2035)	**Policy 2.2: Promote Improved Bus Transport System, Network Restructuring and Route Franchising**			
	Implementation Tools: Establish a subsidy system for the poor/vulnerable transport users	Accessibility-oriented	None	
	Objective 3: To Ensure Effective Traffic Management			
	Policy 3.1: Integration of Travel Demand Management (TDM) in Planning Process			
	Implementation Tools: Provision of incentives to use alternative modes and reduce driving like road and parking pricing, road space allocation (dedicated bus lanes, bike lanes and transit-only lanes)	Mobility-oriented	None	
	Introduction of Parking Management, like Parking cash-out programs, Priority parking for carpools, vanpools, and short-term parkers,	Mobility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Draft Dhaka Structure Plan (2016-2035)	Provision of high capacity transit service in reducing travel demand and shifting travel away from single-occupant vehicles (SOV) to more efficient modes.	Mobility-oriented	None	
	Alternative work arrangements (such as compressed work weeks and telecommuting) to eliminate commute trips one or more days per week.	Mobility-oriented	None	
	Sharing of time and space by staggering office hour (different timing for private and public office) and school and university time can greatly reduce the peak hour traffic volume.	Mobility-oriented	None	
	Using information technology-like, video conferencing between corporate head office and branch office of commercial establishment for important meetings would minimize the need of travel.	Mobility-oriented	None	
	Land use management, Provision of more mixed use development, and Increased densities in transit corridors	Accessibility-oriented	None	

Table 6.1: Accessibility-related Policies, Goals, Objectives, and Strategies in the Selected Policy and Planning Documents (contd.)

Transportation Plan	Policies, Goals, Objectives and Strategies	Focus (Accessibility or Mobility oriented)	Accessibility-related Performance Indicator	Comments
Draft Dhaka Structure Plan (2016-2035)	Build compact communities with sufficient density to support high-frequency transit service.	Accessibility-oriented	None	
	Policy 3.2: Management of Rickshaw-based Transport	Mobility-oriented	None	Introduction of affordable taxi cabs as an alternative to rickshaws remains questionable.
	Implementation Tools: Expedite mass transit development, introduce affordable taxi cab, and limit movement of NMT within neighborhoods and on major roads. But all the measures should be taken up simultaneously so that NMT users do not suffer for want of alternative mode of transport.			

This gave an impression that there is a possibility of implicit or latent manifestation of the notion of accessibility in those plans in the form of theoretical concepts or strategies, etc. Compared to the deductive approach, it is however, more challenging to explore implicit manifestation from the planning documents. Moreover, different documents being drafted in years of gaps and by different authorities, have different choices of words or themes to express similar ideas. To deal with this, the words and themes that might implicitly reflect accessibility were sorted out using ATLAS.ti. A wider range of themes was considered in this inductive approach which includes but not limited to multimodal transport, intermodal transport, public transport, mass transit, reducing travel demand, increasing choice of travel modes, addressing the needs of specific population, connectivity, etc. Here, it is to be noted that the choice of words play an important role in this approach because the same idea could be conveyed in a number of different ways as well as the same word could be used in different contexts. For instance- while Draft Dhaka Structure Plan (2016-2035) mentions 'Providing a greater choice of travel modes', STP, 2005 speaks of 'Provide alternative transportation modes and options'. Therefore, specific words from the themes were also picked as keywords and counted each instance the words appeared and carefully assessed the context in which the words or themes were used.

6.3 FINDINGS AND DISCUSSION

The mixed content-structuring analysis shows that all the planning documents incorporate accessibility- either explicitly or implicitly. Although the extent to which accessibility is explicitly incorporated remains questionable. However, the complexity arises because none of the plans have defined accessibility. Moreover, the term 'accessibility' has been used to convey different ideas in the same document without any clear distinction. For example- RSTP, 2015 used the same term 'accessibility' in conceptualizing functional classification of roads, referring to the percentage of households with different infrastructure services, accessibility to bus stops and accessibility to urban services. As a result, its translation from vision, mission or policy to objectives, strategies or implementation tools remain highly ambiguous.

Mobility and accessibility have often been used interchangeably. Interestingly, sometimes even when some issues, measures or statements explicitly or implicitly reflect accessibility, they are included under the heading of mobility. This observation indicates that mobility has potentially received more direct emphasis than accessibility.

The concept of multimodality as used in this study is largely absent in the plans. The issue of walking or non-motorized transports have come as independent modes and except for STP, 2005, their role as feeder modes has not been adequately emphasized in the objectives or strategies. Added to that, when Draft Dhaka Structure Plan (2016-2035) talked about the role of rickshaws as feeder mode of public transport, ironically it proposed affordable taxi cabs as an alternative to rickshaws. Taxi cabs involve fuel cost and environmental impacts. Moreover, accommodating automobiles like taxi cabs or cars require considerable amount of road and parking space. Considering these impacts, it remains unclear from the document how taxi cabs would offer a sustainable solution. This indicates the underlying premeditated preference of mobility in the planning process. Therefore, the goals, objectives or strategies do not meaningfully reflect multimodal accessibility as the ease of reaching destinations and availing desired opportunities.

Unfortunately, none of the planning documents has incorporated any quantifiable metric or performance indicator of accessibility. This, however, is not surprising given the ambiguity in the concept of accessibility reflected in the plans. Therefore, the absence of any performance indicator in the plans drafted over all these years makes even the noblest goals and objectives go in vain because they hardly have anything to contribute in ensuing implementation stages.

In contrast to the other reviewed documents, Draft Dhaka Structure Plan (2016-2035), the latest one, surprisingly do not mention about accessibility in any of its policy, goal or objective statements. Although it highlights ‘Accessibility to services & facilities’ as one of the parameters of livability (livability, functionality and resilience are included as the three pillars of its vision), the focus revolves around connectivity and mobility. The mobility-oriented planning is also evident in RSTP, 2015 which highlights road network performance through volume-capacity ratio (VCR). However, the entire plan do not have any sort of performance measure on changes in accessibility from proposed road construction or rapid transit projects.

The author does not underestimate the importance of enhancing mobility or connectivity as along with proximity, they are the means of achieving accessibility (Levine, Grengs, Shen, & Shen, 2012). What is important here to understand that it is misleading and even dangerous to mix these concepts and stay vague in determining what they actually want to achieve. These reveal a significant lack of clarity in conceptualizing accessibility at the policy and planning level.

Another striking feature in Draft Dhaka Structure Plan (2016-2035) is the lack of integration among different sectoral plans and the spatial development plan in general. For instance, it speaks about enhanced accessibility by concentrating facilities and indicates about polycentricity to 'reduce long-distance commute'. However, these spatial development concepts are barely reflected in the transportation planning section. Similarly, an objective under the goal 'Making Dhaka Increasingly Functional and Productive' states about increasing economic and employment densities in existing urban areas. However, it totally misses the opportunity of integrating the transportation sector with it and developing any quantifiable performance indicator.

DHUTS, 2010, Draft Dhaka Structure Plan (2016-2035) and RSTP, 2015 have repeatedly focused on enhancing connectivity and minimizing missing links in road network. RSTP, 2015 mentions explicitly about MRT Line 5: "In order to provide a high-capacity, high-speed and frequent public transport system to the city for trips which do not commence or end in the CBD and which will be served by the radial MRT Line 1, MRT Line 2, BRT Line 3, MRT Line 6 and BRT Line 7, the Study Team has identified the need for a circumferential MRT Line 5 that would provide a "bypass" public transportation service for the city's suburban areas and provide good connectivity between suburban zones." Nevertheless, MRT Line 5, the only MRT/BRT line that is aligned in east-west direction in the proposed plan gets little focus for near future **(Figure 6.1)**. It appears that the relatively fewer estimated ridership of MRT Line 5 and the urgency to improve connectivity of the city with CBD through other lines are the reasons behind this. This would have sounded more reasonable if in the meantime, new bus routes with east-west connectivity could have been developed. A map of basic network of the primary bus service has been included in RSTP but no plausible plan is outlined on how and when these will be developed. Focus has been given on integrating primary and secondary bus routes with MRT/BRT system which is indeed required. But until 2035, when all the MRT/BRT lines are expected to be operational, public transport system in the city would possibly suffer from the highly criticized east-west connectivity issue.

MRT Line 4 and Dhaka Elevated Expressway essentially have the same alignment in most parts while BRT Line 3 also overlaps with them in a considerable segment. The point here is not to simply criticize it rather emphasize that there should be adequate and reasonable justification of this overlapping in the proposed plan which is currently absent in these documents. Unless a sound, rational explanation is there, such massive investments would remain questionable.

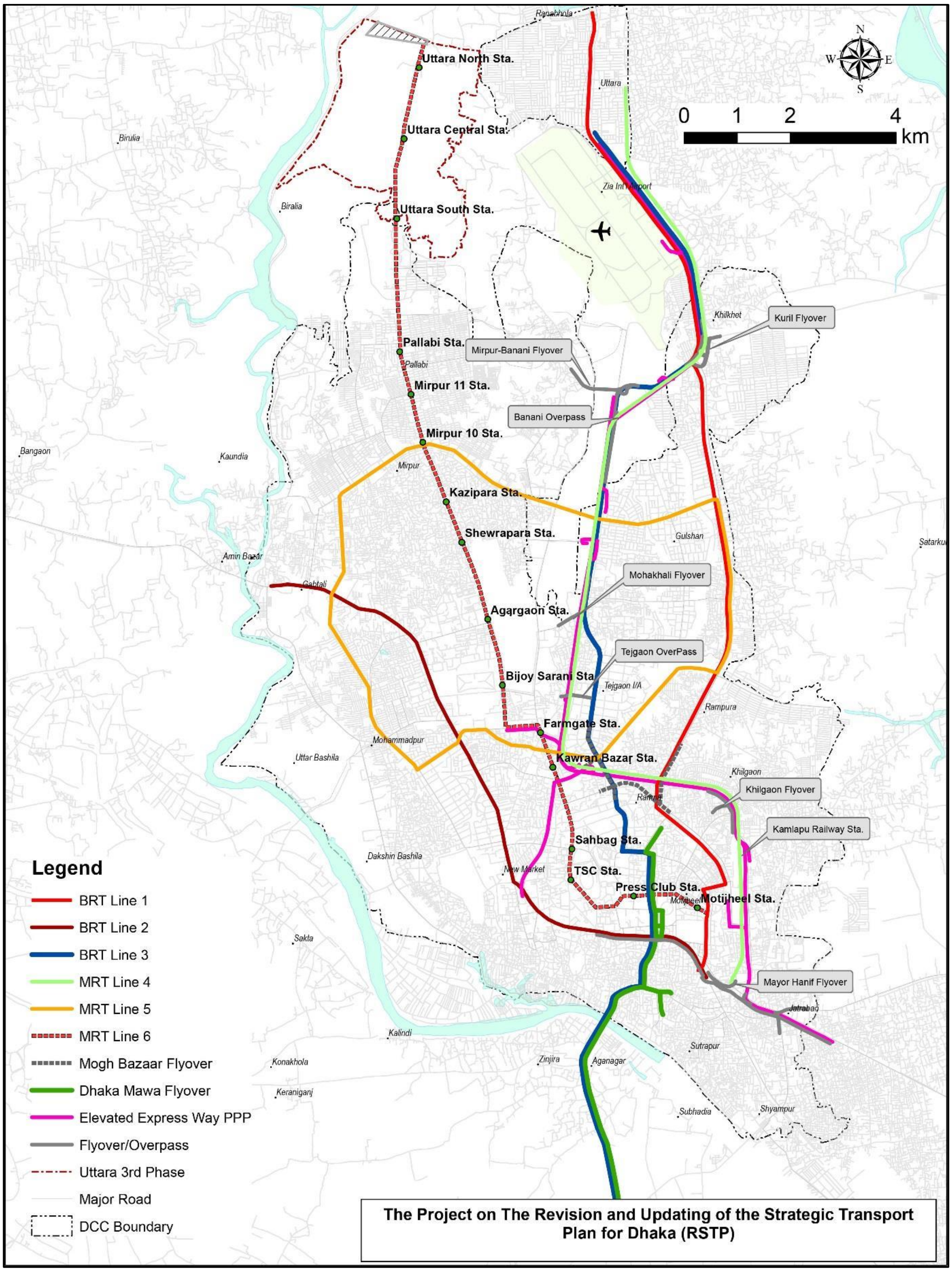

Figure 6.1: Urban transport projects in Dhaka
(Source: RSTP, 2015)

Equity analysis is considered as an integral part of accessibility assessment these days. All the reviewed documents have spoken about better serving the different disadvantaged or marginalized group of population although those policies, goals and objectives have remained vague due to absence of any quantifiable metric. However, since equity analysis was beyond the scope of the current study, the author refrains from critically evaluating such policies, goals and objectives.

6.4 INTEGRATION OF CURRENT RESEARCH FINDINGS AND PROPOSED PLANNING INITIATIVES

6.4.1 Findings on Accessibility and Proposed Planning Initiatives

The ambiguity in defining accessibility, complete absence of performance indicators and both explicit and implicit emphasis on mobility-oriented planning leave little room for any critical assessment of the goals and objectives outlined in the reviewed documents. Again, this reveals that indeed a lot is to be done for effective decision-making process for the city.

First, a clear distinction has to be made among concepts like mobility, accessibility and connectivity. Second, the vision, goals, objectives and strategies should explicitly incorporate accessibility. While enhanced mobility can lead to enhanced accessibility and vice-versa, they are not substitutable and should not be used interchangeably.

Third, the accessibility-related goals and objectives should be translated to quantifiable measures or performance indicators. A simple ridership count estimation or financial feasibility analysis for a new infrastructure investment is barely enough to justify its implementation. Such planning initiatives and investments should be validated by examining the extent to which that bring changes in accessibility level and enhance social equity. This is not possible to assess without clearly stated indicators in the guiding planning documents. This study revealed that nearly 10% of the population have no accessibility to any major destinations by public bus within 60 minutes of travel. Would the proposed planning initiatives bring any luck to these people? If yes, how much change would that bring? Would the propose travel demand management measures reduce modal accessibility gap compared to what we found in the earlier chapter? How would these be linked and contribute to the policies and goals? The existing planning documents include no assessment criteria to answer such vital questions.

Fourth, accessibility needs to be measured for different modes and for different times of the day to reflect the diversity of choice and needs. Down that line, multimodality or first mile/last mile connectivity issue of public transport should be considered. The importance of non-motorized transport and walking has to be reflected in planning process. For example- instead of proposing taxi cabs as feeder modes of public transport, promoting bicycle use through park-and-ride system and separate bicycle lanes is far more sustainable and equitable from social, environmental and economic perspective.

Fifth, along with spatial dimension, temporal dimension should be considered. The earlier chapter showed that non-work trips constitute a considerable share of total trips and therefore, along with CBDs, non-work trip destinations should also have satisfactory level of accessibility. It is possible to have good accessibility during peak hours because of high transit level-of-service but poor accessibility during off-peak hours when more non-work trips are made due to lack of transit service to the desired destinations. It is again possible to have good public transit accessibility all day long but poor walk or bicycle accessibility due to absence of dedicated bicycle or pedestrian lanes. Aggregated accessibility measures would not be able to capture this temporal and modal differences. The reviewed documents have hardly addressed the temporal issue- the few occasions temporal dimension was considered, the focus has solely been on peak hour. At the same time, accessibility to various non-work facilities has been incorporated in most of the documents. But no clear linkage could be found between the two given that accessibility to non-work activities would require focus on off-peak hour as well. Findings from earlier chapter showed that trip destinations varies with time-of-day and trip purpose. However, the documents seemed to take a logical leap and totally disregarded this spatial and temporal link.

6.4.2 Findings on Travel Behavior and Proposed Planning Initiatives

The study found strong influence of built environment factors on travel behavior. The reviewed planning documents have incorporated built environment factors e.g. density, land use mix, etc. Accessibility to bus stop was also included in RSTP, 2015 but to reflect level-of-service and was measured in ordinal scale.

Proposed Transit Oriented Development (TOD) in RSTP, 2015 have spoken about density and land use mix, which are to be integrated with the MRT/BRT stations in future. The Draft Dhaka Structure Plan (2016-2035) has also outlined the models of

Neighborhood Development Concept (NDC) and Pedestrian Oriented Development (POD). However, all these have been outlined in strictly theoretical fashion and no plausible plan or quantifiable metric could be found there.

Broadly speaking, the inclusion of built environment or land use factors in these documents have generally been quite theoretical in manner so far. Draft Dhaka Structure Plan (2016-2035) mentions about more specific outlines of these in the upcoming Detailed Area Plan (DAP). As the DAP is not there yet, these proposals could not be evaluated. However, it is expected that the DAP will identify specific locations where TOD, NDC or POD would be promoted. Moreover, simplified ideas like 'compact development', 'mixed use' or 'higher density' should be adequately defined and quantified to guide development according to the plan.

RSTP, 2015 and Draft Dhaka Structure Plan (2016-2035) include several mobility-limiting strategies to discourage private motorized vehicle use. This is consistent to the current study outcomes where it was found that built environment factors, unless supported by mobility-limiting strategies, would not be able to bring drastic changes in private car ownership and use. It is now required to assess which mobility-limiting strategies would be effective in Dhaka's context. Also, mobility-limiting strategies should not disproportionately affect the disadvantaged group of population. For example- limiting rickshaw movements and introducing 'affordable' taxi cabs, along with concerns like the ones talked about in the earlier sub-section, brings up some simple questions: how much affordable taxi cabs could be as feeder modes given the fuel cost associated with running any motorized vehicle? Who would primarily be the users of those taxi cabs to complete their first mile/last mile journeys? And even more importantly, for whom, this affordability is to be defined and measured? Such issues need to be considered before implementing any strategy.

Draft Dhaka Structure Plan (2016-2035) has offered some promising strategies e.g. staggered office hours and using information technology to reduce the need for travel. These are some of the areas beyond the scope of our study. Nevertheless, it is recommended to conduct careful analysis before implementing any of those strategies. Such strategies need to be integrated with the overall transportation system. For example- staggered office hours would require adequate transit service to link trip origins and destinations at different time periods of the day other than the traditionally defined peak hours.

6.5 CONCLUDING REMARKS

The evaluation sketched in this chapter is based on reviewing the documents. This study could not incorporate the complex decision-making process that work in the background before and during the documents are drafted. An understanding of the decision-making process including social and political influences, if any, would possibly shed more light in this area. That is, undoubtedly, a highly challenging task.

Nevertheless, this chapter reveals some of the striking pitfalls in incorporating the concept of accessibility as well as addressing accessibility-enhancing or mobility-limiting strategies in our transportation planning. The clearest drawback of the reviewed documents is their ambiguity or vagueness in defining the crucial concepts like accessibility, mobility or connectivity and the resultant absence of any performance indicator to evaluate the various planning initiatives. Unless the concepts are defined clearly and the policy and goals are translated to meaningful objectives and strategies, the documents would serve no actual purpose of guiding the city's development process.

Chapter 7

Conclusion

7.1 SUMMARY OF FINDINGS AND CONTRIBUTION TO EXISTING RESEARCH BASE

The aim of this research was to explore and quantify multimodal accessibility and its effect on travel behavior in Dhaka and synthesize its research and policy implications. The fourth chapter focused on characterizing accessibility. In exploring accessibility scenario, both spatial and temporal dimensions were considered and statistically significant major destinations or activity hubs of the city were identified. The uniqueness of this approach demonstrated that there is clear relationship between trip purpose, time-of-day and trip destinations and these three cannot be thought in separation from one another. The importance of the major destinations could be further validated by the finding that people travel for statistically significantly longer distance and time to reach the major destinations compared to other destinations. Another novelty of this study is its approach in dealing with limited available database. In contrast to prior research dependent on extensive, highly disaggregated and dynamic database, this study has put forward an alternative way of dealing with data-deprived situations like ours. Data unavailability is found in different other developing countries as well and this approach can be useful in those contexts as well. This study could therefore, offer opportunities of research applicability and knowledge transfer for similar developing countries and data-deprived contexts. In the context of policymaking and planning in Dhaka, the proposed methodology can be applied for bus route rationalization here. The method of considering of spatial and temporal perspective in identifying major destinations can be used to come up with a demand-sensitive public bus service system. For example- higher frequency of bus services can be provided to morning peak major destinations during morning peak and similarly for other time-of-day and major destinations. Such planning would allow better resource utilization as well as more reliable, quality public transport service.

It was found that multimodal accessibility to major destinations is significantly lower than private car accessibility during any time-of-day in Dhaka. The findings support modal mismatch theory from spatiotemporal perspective: irrespective of time-of-day and place of residence, proximity to major destinations has substantially different effect on car and bus users. This difference is so massive that living far-off from the major destinations still gives better accessibility to car users compared to bus users living close to the major destinations. Having a car, therefore, makes a huge difference.

Travel behavior in Dhaka has been explored in the fifth chapter. Binary logistic model has been used in explaining work and non-work mode choice and household car ownership decisions. Several individual and household and built environment attributes showed statistical significance in the models. Unsurprisingly, car ownership, income and holding a driver's license have overwhelming influence on car mode choice indicating people's tendency to use car as soon as they can afford to buy one. Similar thing can be said for car ownership as well. Women were more likely to use car compared to men possibly due to their complex trip-chaining pattern, involvement in diversified non-work activities and safety issues.

The separation of base and expanded models enabled to specifically understand the extent to which built environment variables affect travel behavior. Several built environment variables e.g. accessibility, entropy, connectivity, etc. showed statistical relevance and all the models showed explicit improvement after including built environment variables. Accessibility in particular has been found to be quite promising. Increase in multimodal accessibility revealed statistical relevance in decreasing car mode choice. Lower multimodal accessibility compared to car accessibility as illustrated by modal accessibility gap has been found to be influencing car ownership. These evidently speak of the vital role of accessibility in travel behavior and strengthens the ground to advocate for effective integration of accessibility issues in transportation planning in Dhaka.

The sixth chapter involves reviewing policies and plans. Reviewing relevant transportation policy and planning documents strikingly revealed the ambiguity in defining accessibility and complete absence of any quantifiable metric to measure accessibility. A clear lack of clarity in distinguishing concepts like mobility, accessibility and connectivity, etc. is evident in those documents. This visibly explains why accessibility has not yet been effectively translated beyond pen and paper. The dearth of attention in addressing the first mile/last mile connectivity issue in public transport travel was also noticed. Moreover, temporal dimension of any sort and issues related to non-work trips are largely absent in those policies and plans.

In a nutshell, this research suggests that accessibility is crucial in travel behavior decisions in Dhaka and therefore, can be a fundamental tool in our planning process. A clear conceptualization of accessibility is of huge importance to integrate it in the policymaking and planning process and effectively translate the policies into practice.

7.2 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Most of the limitations encountered in this study are associated with limitations in available data. A more up-to-date database could have been more useful. However, it is strongly felt that a database without reasonable assumptions in data collection and updating is less than ideal. Therefore, the most reliable and consistent databases required for this study have been used in spite of their not being the most recent one in some cases.

The study had to depend on data of employment opportunities only since data of other facilities were not available for Dhaka. Data on other spatial opportunities could unquestionably enrich and refine the outcome in future. Assumption had to be made as well that the number of total persons employed to be equal of the number of employment opportunities available in the TAZs. The author acknowledges that this might not always be true.

Attitudinal information could not be incorporated in modeling mode choice in this study. Future research should attempt to address this limitation. Ability to geocode trip origin and destinations could have also produced a more precise estimation. The database used here did not contain any data on ridesharing services since ridesharing services like Uber or Pathao started their journey in 2016. Thus this study could not consider ridesharing services. However, the author acknowledges the importance of conducting research on the impact of ridesharing services on travel behavior here. Study can also be done on motorcycle ownership here given an increasing trend of new motorcycle registration and motorcycle use is noticed in Dhaka (Bangladesh Road Transport Authority, 2019, April 8). At the same time, future research should consider activity-based modeling to better reflect dynamic and complex trip chaining pattern and mode choice decisions in Dhaka. This research can further be used to explore residential self-selection in Dhaka. Another direction that this research can take is to explore the potential of different accessibility-enhancing and mobility-limiting strategies here.

Since this study focused on estimating accessibility by public bus and car only, future research can concentrate on other modes as well. Dhaka is a city with diversified modes of travel playing key roles in the city’s transportation scenario. Developing knowledge base surrounding other modes’ accessibility is also important in the local context.

Moreover, walking has been considered as the feeder mode of public bus to estimate accessibility here. Similar methodology can be applied to understand rickshaw-public bus accessibility scenario and even compare walk-bus and rickshaw-bus accessibility in Dhaka.

To summarize, this research showed evidence that there is a lot to do in policymaking and planning process to shape the transportation sector of Dhaka. Putting differently, the city and its planning process is currently standing at a position where urban planners, transportation experts and policymakers have a lot to contribute. There needs to be explicit integration of research and evidence backed propositions in policymaking and planning process. At the same time, it is high time attention is given in creating a comprehensive database with up-to-date information.

References:

Ahmed, T. (2016). *Exploring trip chain behaviour of the working population in Dhaka.* (Masters thesis), Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

Akar, G., & Guldmann, J.-M. (2012). Another look at vehicle miles traveled: Determinants of vehicle use in two-vehicle households. *Transportation Research Record: Journal of the Transportation Research Board 2322*(1), 110-118. doi:https://doi.org/10.3141/2322-12

Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geographical Analysis, 27*(2), 93-115.

Anselin, L. (2018). Contiguity-Based Spatial Weights. Retrieved from https://geodacenter.github.io/workbook/4a_contig_weights/lab4a.html

Anselin, L. (2019). Local Spatial Autocorrelation (1). Retrieved from https://geodacenter.github.io/workbook/6a_local_auto/lab6a.html

Apparicio, P., Abdelmajid, M., Riva, M., & Shearmur, R. (2008). Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. *International Journal of Health Geographics, 7*(1), 7. doi:10.1186/1476-072x-7-7

Bangladesh Bureau of Statistics. (2014). *Bangladesh Population and Housing Census 2011 (Urban Area Report)*. Retrieved from http://203.112.218.65:8008/WebTestApplication/userfiles/Image/National%20Reports/Population%20%20Housing%20Census%202011.pdf.

Bangladesh Road Transport Authority. (2019, April 8). Number of Registered Motor Vehicles in Dhaka (Yearwise). Retrieved from http://www.brta.gov.bd/

Beimborn, E. A., Greenwald, M. J., & Jin, X. (2003). Accessibility, connectivity, and captivity: Impacts on transit choice. *Transportation Research Record: Journal of the Transportation Research Board, 1835*(1), 1-9. doi:https://doi.org/10.3141/1835-01

Blumenberg, E., & Manville, M. (2004). Beyond the spatial mismatch: Welfare recipients and transportation policy. *Journal of Planning Literature, 19*(2), 182-205. doi:10.1177/0885412204269103

Blumenberg, E., & Ong, P. (2001). Cars, buses, and jobs: Welfare participants and employment access in Los Angeles. *Transportation Research Record: Journal of the Transportation Research Board, 1756*(1), 22-31.

Blumenberg, E., & Pierce, G. (2012). Automobile ownership and travel by the poor: Evidence from the 2009 National Household Travel Survey. *Transportation Research Record: Journal of the Transportation Research Board, 2320*(1), 28-36. doi:https://doi.org/10.3141/2320-04

Boarnet, M. G., Giuliano, G., Hou, Y., & Shin, E. J. (2017). First/Last mile transit access as an equity planning issue. *Transportation Research Part A: Policy and Practice, 103*, 296-310.

Boisjoly, G., & El-Geneidy, A. (2016). Daily fluctuations in transit and job availability: A comparative assessment of time-sensitive accessibility measures. *Journal of Transport Geography, 52*, 73-81. doi:10.1016/j.jtrangeo.2016.03.004

Boisjoly, G., & El-Geneidy, A. M. (2017). How to get there? A critical assessment of accessibility objectives and indicators in metropolitan transportation plans. *Transport Policy, 55*, 38-50.

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the impacts of residential self-selection on travel behaviour: A focus on empirical findings. *Transport Reviews, 29*(3), 359-395.

Cervero, R. (1988). Land-use mixing and suburban mobility. *Transportation Quarterly, 42*(3), 429-446.

Cervero, R. (1996). Mixed land-uses and Commuting: Evidence from the American Housing Survey. *Transportation Research Part A: Policy and Practice, 30*(5), 361-377.

Cervero, R. (2002). Built environments and mode choice: Toward a normative framework. *Transportation Research Part D: Transport and Environment, 7*(4), 265-284. doi:https://doi.org/10.1016/S1361-9209(01)00024-4

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199-219.

Chatman, D. G. (2008). Deconstructing development density: Quality, quantity and price effects on household non-work travel. *Transportation Research Part A: Policy and Practice, 42*(7), 1008-1030.

Chu, Y.-L. (2002). Automobile ownership analysis using ordered probit models. *Transportation Research Record: Journal of the Transportation Research Board, 1805*(1), 60-67. doi:https://doi.org/10.3141/1805-08

Clifton, K., & Muhs, C. D. (2012). Capturing and representing multimodal trips in travel surveys. *Transportation Research Record: Journal of the Transportation Research Board, 2285*(1), 74-83. doi:10.3141/2285-09

Cui, B., Boisjoly, G., El-Geneidy, A., & Levinson, D. (2019). Accessibility and the journey to work through the lens of equity. *Journal of Transport Geography, 74*, 269-277.

Currie, G. (2004). Gap analysis of public transport needs: Measuring spatial distribution of public transport needs and identifying gaps in the quality of public transport provision. *Transportation Research Record: Journal of the Transportation Research Board, 1895*, 137-146.

Deboosere, R., & El-Geneidy, A. (2018). Evaluating equity and accessibility to jobs by public transport across Canada. *Journal of Transport Geography, 73*, 54-63.

Demographia. (2019). *Demographia World Urban Areas (15th Annual Edition)*. Retrieved from http://www.demographia.com/db-worldua.pdf

Dhaka Transport Coordination Board, & Ministry of Communications. (2010). *Preparatory Survey Report on Dhaka Urban Transport Network Development Study (DHUTS) in Bangladesh: Final Report*. Retrieved from http://open_jicareport.jica.go.jp/710/710/710_101_11996774.html.

Ding, C., Wang, Y., Tang, T., Mishra, S., & Liu, C. (2018). Joint analysis of the spatial impacts of built environment on car ownership and travel mode choice. *Transportation Research Part D: Transport and Environment, 60*, 28-40.

Dissanayake, D., & Morikawa, T. (2002). Household travel behavior in developing countries: Nested logit model of vehicle ownership, mode choice, and trip chaining. *Transportation Research Record: Journal of the Transportation Research Board, 1805*(1), 45-52. doi:https://doi.org/10.3141/1805-06

El-Geneidy, A., Levinson, D., Diab, E., Boisjoly, G., Verbich, D., & Loong, C. (2016). The cost of equity: Assessing transit accessibility and social disparity using total travel cost. *Transportation Research Part A: Policy and Practice, 91*, 302-316.

El-Geneidy, A. M., & Levinson, D. M. (2006). *Access to destinations: Development of accessibility measures*. Retrieved from University of Minnesota Digital Conservancy: https://conservancy.umn.edu/handle/11299/638

Ellwood, D. T. (1986). The spatial mismatch hypothesis: Are there teenage jobs missing in the ghetto? *The black youth employment crisis* (pp. 147-190). Chicago, IL: University of Chicago Press.

Enam, A., & Choudhury, C. F. (2011). Methodological issues in developing mode choice models for Dhaka, Bangladesh. *Transportation Research Record: Journal of the Transportation Research Board, 2239*(1), 84-92.

Etminani-Ghasrodashti, R., & Ardeshiri, M. (2016). The impacts of built environment on home-based work and non-work trips: An empirical study from Iran. *Transportation Research Part A: Policy and Practice, 85*, 196-207. doi:https://doi.org/10.1016/j.tra.2016.01.013

Ewing, R. (1993). Transportation service standards-as if people matter. *Transportation Research Record: Journal of the Transportation Research Board*(1400), 10-17.

Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American Planning Association, 76*(3), 265-294.

Ewing, R., DeAnna, M., & Li, S.-C. (1996). Land use impacts on trip generation rates. *Transportation Research Record: Journal of the Transportation Research Board, 1518*(1), 1-6. doi:https://doi.org/10.1177/0361198196151800101

Ewing, R., Schroeer, W., & Greene, W. (2004). School location and student travel analysis of factors affecting mode choice. *Transportation Research Record: Journal of the Transportation Research Board, 1895*(1), 55-63. doi:https://doi.org/10.3141/1895-08

Farber, S., Morang, M. Z., & Widener, M. J. (2014). Temporal variability in transit-based accessibility to supermarkets. *Applied Geography, 53*, 149-159. doi:10.1016/j.apgeog.2014.06.012

Ford, A., Barr, S., Dawson, R., & James, P. (2015). Transport accessibility analysis using GIS: Assessing sustainable transport in London. *ISPRS International Journal of Geo-Information, 4*(1), 124-149.

Frank, L. D., & Engelke, P. (2005). Multiple impacts of the built environment on public health: Walkable places and the exposure to air pollution. *International Regional Science Review, 28*(2), 193-216.

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.

Geurs, K. T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography, 12*(2), 127-140.

Gómez-Gélvez, J. A., & Obando, C. (2013). Modeling car ownership in urban areas of developing countries: case study of Bogotá, Colombia. *Transportation Research Record: Journal of the Transportation Research Board, 2394*(1), 111-118. doi:https://doi.org/10.3141/2394-14

Gould, P. R. (1969). *Spatial Diffusion, Resource Paper No. 4*. Retrieved from Washington, D.C.: https://files.eric.ed.gov/fulltext/ED120029.pdf

Grengs, J. (2010). Job accessibility and the modal mismatch in Detroit. *Journal of Transport Geography, 18*(1), 42-54. doi:10.1016/j.jtrangeo.2009.01.012

Grengs, J., Levine, J., Shen, Q., & Shen, Q. (2010). Intermetropolitan comparison of transportation accessibility: Sorting out mobility and proximity in San Francisco and Washington, D.C. *Journal of Planning Education and Research, 29*(4), 427-443. doi:10.1177/0739456x10363278

Guy, C. M. (1983). The assessment of access to local shopping opportunities: A comparison of accessibility measures. *Environment and Planning B: Planning and Design, 10*(2), 219-237.

Habib, M. A., & Daisy, N. S. (2013). Modeling frequency and duration of out-of-home participation in physical activity by school-age children. *Transportation Research Record: Journal of the Transportation Research Board, 2357*(1), 116-124.

Hägerstrand, T. (1970). What about people in regional science? *Papers in Regional Science, 24*(1), 6-21.

Handy, S. (2005). Planning for accessibility: In theory and in practice. In D. M. Levinson & K. Krizek (Eds.), *Access to destinations* (pp. 131-147): Emerald Group Publishing Limited.

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment, 10*(6), 427-444.

Handy, S. L. (1992). *Regional versus local accessibility: Variations in suburban form and the effects on non-work travel.* (Doctoral dissertation), University of California Transportation Center, California, the USA.

Handy, S. L. (2002). *Accessibility-vs. Mobility-Enhancing Strategies for Addressing Automobile Dependence in the US*: Institute of Transportation Studies, UC Davis.

Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: An exploration of issues and alternatives. *Environment and Planning A: Economy and Space, 29*(7), 1175-1194.

Hansen, W. G. (1959). *Accessibility and residential growth.* (Doctoral dissertation), Massachusetts Institute of Technology, Massachusetts, the USA.

Hanson, S. (1982). The determinants of daily travel-activity patterns: Relative location and sociodemographic factors. *Urban Geography, 3*(3), 179-202.

Hanson, S., & Schwab, M. (1987). Accessibility and intraurban travel. *Environment and Planning A: Economy and Space, 19*(6), 735-748.

Hass, K. (2009). *Measuring accessibility of regional parks: A comparison of three GIS techniques (Master's thesis).*

Hess, D. B. (2016). Access to employment for adults in poverty in the Buffalo-Niagara region. *Urban Studies, 42*(7), 1177-1200. doi:10.1080/00420980500121384

Hewko, J., Smoyer-Tomic, K. E., & Hodgson, M. J. (2002). Measuring neighbourhood spatial accessibility to urban amenities: Does aggregation error matter? *Environment and Planning A: Economy and Space, 34*(7), 1185-1206.

Ingram, D. R. (1971). The concept of accessibility: A search for an operational form. *Regional studies, 5*(2), 101-107.

Japan International Cooperation Agency, & Dhaka Transport Coordination Authority. (2015). *The Project on the Revision and Updating of the Strategic Transport Plan for Dhaka*. Retrieved from http://www.rthd.gov.bd/docs/Institution%20Development%20(RSTP).pdf.

Kain, J. F. (1968). Housing segregation, Negro employment, and metropolitan decentralization. *The Quarterly Journal of Economics, 82*(2), 175-197. doi:10.2307/1885893

Kawabata, M. (2003a). Job access and employment among low-skilled autoless workers in US metropolitan areas. *Environment and Planning A: Economy and Space, 35*(9), 1651 - 1668.

Kawabata, M. (2003b). Job accessibility by travel mode in US metropolitan areas. *Theory and Applications of GIS, 11*(2), 43-50.

Kawabata, M. (2009). Spatiotemporal dimensions of modal accessibility disparity in Boston and San Francisco. *Environment and Planning A: Economy and Space, 41*(1), 183-198.

Kawabata, M., & Shen, Q. (2006). Job accessibility as an indicator of auto-oriented urban structure- A comparison of Boston and Los Angeles with Tokyo. *Environment and Planning B: Planning and Design, 33*(1), 115-130. doi:10.1068/b31144

Kawabata, M., & Shen, Q. (2007). Commuting inequality between cars and public transit: The case of the San Francisco Bay Area, 1990-2000. *Urban Studies, 44*(9), 1759-1780.

Kawabata, M., & Takahashi, A. (2005). Spatial dimensions of job accessibility by commuting time and mode in Tokyo metropolitan area. *Theory and Applications of GIS, 13*(2), 31-40.

Khan, M., Choudhury, C. F., & Wang, J. (2011). Modeling preference for school bus service in Dhaka, Bangladesh: Stated preference approach. *Transportation Research Record: Journal of the Transportation Research Board, 2239*(1), 64-73.

Khattak, A. J., & Rodriguez, D. (2005). Travel behavior in neo-traditional neighborhood developments: A Case Study in USA. *Transportation Research Part A: Policy and Practice, 39*(6), 481-500.

Kim, S., & Ulfarsson, G. F. (2004). Travel mode choice of the elderly: Effects of personal, household, neighborhood, and trip characteristics. *Transportation Research Record, 1894*(1), 117-126. doi:https://doi.org/10.3141/1894-13

Kitamura, R., Akiyama, T., Yamamoto, T., & Golob, T. F. (2001). Accessibility in a metropolis: Toward a better understanding of land use and travel. *Transportation Research Record: Journal of the Transportation Research Board, 1780*(1), 64-75. doi:https://doi.org/10.3141/1780-08

Kitamura, R., Mokhtarian, P. L., & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in The San Francisco Bay Area. *Transportation, 24*(2), 125-158. doi:https://doi.org/10.1023/A:1017959825565

Kockelman, K. M. (1997). Travel behavior as function of accessibility, land use mixing, and land use balance: Evidence from San Francisco Bay Area. *Transportation Research Record: Journal of the Transportation Research Board 1607*(1), 116-125. doi:https://doi.org/10.3141/1607-16

Kwan, M. P. (1998). Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical analysis, 30*(3), 191-216.

Kwok, R. C., & Yeh, A. G. (2004). The use of modal accessibility gap as an indicator for sustainable transport development. *Environment and Planning A: Economy and Space, 36*(5), 921-936.

LaMondia, J. J., Blackmar, C. E., & Bhat, C. R. (2010). *Comparing transit accessibility measures: A case study of access to healthcare facilities.* Paper presented at the Proceedings of the 89rd Annual Meeting of Transportation Research Board, Washington, DC, USA.

Lei, T. L., & Church, R. L. (2010). Mapping transit-based access: Integrating GIS, routes and schedules. *International Journal of Geographical Information Science, 24*(2), 283-304.

Levine, J., Grengs, J., Shen, Q., & Shen, Q. (2012). Does accessibility require density or speed? *Journal of the American Planning Association, 78*(2), 157-172. doi:10.1080/01944363.2012.677119

Li, J., Walker, J. L., Srinivasan, S., & Anderson, W. P. (2010). Modeling private car ownership in China: Investigation of urban form impact across megacities. *Transportation Research Record: Journal of the Transportation Research Board, 2193*(1), 76-84. doi:https://doi.org/10.3141/2193-10

Linneker, B. J., & Spence, N. A. (1992). Accessibility measures compared in an analysis of the impact of the M25 London Orbital Motorway on Britain. *Environment and Planning A: Economy and Space, 24*(8), 1137-1154.

Liu, R., Chen, Y., Wu, J., Xu, T., Gao, L., & Zhao, X. (2018). Mapping spatial accessibility of public transportation network in an urban area–A case study of Shanghai Hongqiao Transportation Hub. *Transportation research part D: transport and environment, 59*, 478-495.

Lune, H., & Berg, B. L. (2016). *Qualitative research methods for the social sciences (9th ed.)*. Essex, England: Pearson Education Limited.

Luo, W., & Wang, F. (2003). Measures of spatial accessibility to health care in a GIS environment: Synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design, 30*(6), 865-884.

Ma, J., Liu, Z., & Chai, Y. (2015). The impact of urban form on CO2 Emission from work and non-work trips: The case of Beijing, China. *Habitat International, 47*, 1-10. doi:https://doi.org/10.1016/j.habitatint.2014.12.007

Maat, K., & Konings, R. (2018). Accessibility or innovation? Store shopping trips versus online shopping. *Transportation Research Record: Journal of the Transportation Research Board, 2672*(50), 1-10.

Maltha, Y., Kroesen, M., Van Wee, B., & van Daalen, E. (2017). Changing influence of factors explaining household car ownership levels in the netherlands. *Transportation Research Record, 2666*(1), 103-111. doi:https://doi.org/10.3141/2666-12

Manaugh, K., Badami, M. G., & El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport policy, 37*, 167-176.

Matas, A., Raymond, J.-L., & Roig, J.-L. (2009). Car ownership and access to jobs in Spain. *Transportation Research Part A: Policy and Practice, 43*(6), 607-617.

Mavoa, S., Witten, K., McCreanor, T., & O'Sullivan, D. (2012). GIS based destination accessibility via public transit and walking in Auckland, New Zealand. *Journal of Transport Geography, 20*(1), 15-22. doi:10.1016/j.jtrangeo.2011.10.001

Mayring, P. (2014). *Qualitative content analysis: Theoretical foundation, basic procedures and software solution* Retrieved from https://www.ssoar.info/ssoar/bitstream/handle/document/39517/ssoar-2014-mayring-Qualitative_content_analysis_theoretical_foundation.pdf

McGuckin, N., & Murakami, E. (1999). Examining trip-chaining behavior: Comparison of travel by men and women. *Transportation research record, 1693*(1), 79-85. doi:https://doi.org/10.3141/1693-12

Merlin, L. A. (2014). *Accessibility, travel behavior, and urban form change.* (Doctoral dissertation), The University of North Carolina at Chapel Hill, the USA.

Merlin, L. A. (2017). A portrait of accessibility change for four US metropolitan areas. *Journal of Transport and Land Use, 10*(1), 309–336 doi:10.5198/jtlu/2015.808

Ministry of Communications, & Dhaka Transport Coordination Board. (2005). *Strategic Transport Plan (STP) for Dhaka*. Retrieved from http://fpd-bd.com/wp-content/uploads/2015/07/Strategic-Transport-Plan-Draft-2005.pdf.

Ministry of Communications, & Planning Commission. (2008). *National Integrated Multi-modal Transport Policy (NIMTP)*. Retrieved from http://fpd-bd.com/wp-content/uploads/2015/07/Integrated-Multi-Modal-Transport-Model-Draft-Final-2008.pdf.

Moniruzzaman, M., & Páez, A. (2012). Accessibility to transit, by transit, and mode share: Application of a logistic model with spatial filters. *Journal of Transport Geography, 24*, 198-205.

Munshi, T. (2016). Built environment and mode choice relationship for commute travel in the city of Rajkot, India. *Transportation Research Part D: Transport and Environment, 44*, 239-253.

Niedzielski, M., & Śleszyński, P. (2008). Analyzing accessibility by transport mode in Warsaw, Poland. *Geographia Polonica, 81*(2), 61-78.

Nippon Koei Co. Ltd. (2015). *Study on Dhaka Mass Rapid Transit East-West Line Project in Bangladesh*. Retrieved from https://www.meti.go.jp/meti_lib/report/2015fy/280235.pdf.

Oakil, A. T. M., Manting, D., & Nijland, H. (2016). Determinants of car ownership among young households in the Netherlands: The role of urbanisation and demographic and economic characteristics. *Journal of Transport Geography, 51*, 229-235.

Ong, P. M., & Miller, D. (2005). Spatial and transportation mismatch in Los Angeles. *Journal of Planning Education and Research, 25*(1), 43-56.

Owen, A., & Levinson, D. M. (2015). Modeling the commute mode share of transit using continuous accessibility to jobs. *Transportation Research Part A: Policy and Practice, 74*, 110-122.

Preston, J., & Rajé, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography, 15*(3), 151-160.

R Core Team. (2018). R: A Language and Environment for Statistical Computing. Retrieved from https://www.R-project.org/

Rajdhani Unnayan Katripakkha. (n.d.). *Draft Dhaka Structure Plan 2016- 2035.* Retrieved from http://www.rajukdhaka.gov.bd/rajuk/image/slideshow/Dhaka_Structural_Plan.html.

Sanchez, T. W. (1999). The connection between public transit and employment: The cases of Portland and Atlanta. *Journal of the American Planning Association, 65*(3), 284-296.

Schlossberg, M., Greene, J., Phillips, P. P., Johnson, B., & Parker, B. (2006). School Trips: Effects of urban form and distance on travel mode. *Journal of the American Planning Association, 72*(3), 337-346.

Schmöcker, J.-D., Quddus, M. A., Noland, R. B., & Bell, M. G. (2008). Mode choice of older and disabled people: A case study of shopping trips in London. *Journal of Transport Geography, 16*(4), 257-267. doi:https://doi.org/10.1016/j.jtrangeo.2007.07.002

Shen, Q. (1998). Location Characteristics of inner-city neighborhoods and employment accessibility of Low-wage workers. *Environment and Planning B: Planning and Design, 25*(3), 345-365.

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. doi:https://doi.org/10.1016/j.tra.2016.08.027

Siddique, M. A. B., & Choudhury, C. F. (2017). Modelling the behavioural response to congestion pricing in Dhaka, Bangladesh. *Transportation in Developing Economies, 3*(23), 1-13. doi:https://doi.org/10.1007/s40890-017-0052-y

Srinivasan, S., & Rogers, P. (2005). Travel behavior of low-income residents: Studying two contrasting locations in the city of Chennai, India. *Journal of Transport Geography, 13*(3), 265-274.

Stępniak, M., Pritchard, J. P., Geurs, K. T., & Goliszek, S. (2019). The impact of temporal resolution on public transport accessibility measurement: Review and case study in Poland. *Journal of Transport Geography, 75*, 8-24.

Stevens, M. R. (2017). Does compact development make people drive less? *Journal of the American Planning Association, 83*(1), 7-18.

Sun, B., Ermagun, A., & Dan, B. (2017). Built environmental impacts on commuting mode choice and distance: Evidence from Shanghai. *Transportation Research Part D: Transport and Environment, 52*, 441-453.

Sun, X., Wilmot, C. G., & Kasturi, T. (1998). Household travel, household characteristics, and land use: An empirical study from the 1994 Portland Activity-Based Travel Survey. *Transportation Research Record: Journal of the Transportation Research Board, 1617*(1), 10-17. doi:https://doi.org/10.3141/1617-02

The Accessibility Observatory. (2019). Access Across America. Retrieved from http://access.umn.edu/research/america/index.html

Truong, L. T., & Somenahalli, S. V. (2015). Exploring frequency of public transport use among older adults: A study in Adelaide, Australia. *Travel behaviour and society, 2*(3), 148-155. doi:https://doi.org/10.1016/j.tbs.2014.12.004

Van den Berg, P., Arentze, T., & Timmermans, H. (2011). Estimating social travel demand of senior citizens in the Netherlands. *Journal of Transport Geography, 19*(2), 323-331. doi:https://doi.org/10.1016/j.jtrangeo.2010.03.018

Vance, C., & Hedel, R. (2007). The impact of urban form on automobile travel: Disentangling causation from correlation. *Transportation, 34*(5), 575-588.

Vickerman, R. W. (1974). Accessibility, attraction, and potential: A review of some concepts and their use in determining mobility. *Environment and Planning A: Economy and Space, 6*(6), 675-691.

Victoria Transport Policy Institute. (2019, 21 March). Multi-Modal Level-of-Service Indicators: Tools for Evaluating the Quality of Transport Services and Facilities. Retrieved from https://www.vtpi.org/tdm/tdm129.htm

Whelan, G. (2007). Modelling car ownership in Great Britain. *Transportation Research Part A: Policy and Practice, 41*(3), 205-219.

Widener, M. J., Minaker, L., Farber, S., Allen, J., Vitali, B., Coleman, P. C., & Cook, B. (2017). How do changes in the daily food and transportation environments affect grocery store accessibility? *Applied geography, 83*, 46-62.

Wu, H., & Levinson, D. (2019). *Access across Australia*. Retrieved from http://hdl.handle.net/2123/20509

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.

Zegras, P. C. (2004). Influence of land use on travel behavior in Santiago, Chile. *Transportation Research Record: Journal of the Transportation Research Board, 1898*(1), 175-182. doi:https://doi.org/10.3141/1898-21

Zegras, P. C. (2005). *Sustainable urban mobility: Exploring the role of the built environment.* (Doctoral dissertation), Massachusetts Institute of Technology, Massachusetts, the USA.

Zegras, P. C. (2010). The built environment and motor vehicle ownership and use: Evidence from Santiago de Chile. *Urban Studies, 47*(8), 1793-1817.

Zhang, M. (2004). The role of land use in travel mode choice: Evidence from Boston and Hong Kong. *Journal of the American Planning Association, 70*(3), 344-360.

Appendix A: Descriptive Statistics of Accessibility Scores

Table A.1: Accessibility by Walk-Bus and Car: Morning Peak

	30 Minutes		45 Minutes		60 Minutes	
	Walk-Bus	**Car**	**Walk-Bus**	**Car**	**Walk-Bus**	**Car**
Average	14,096.46	155,165.67	26,605.50	204,491.48	37,383.37	236,488.01
Standard Deviation	27,570.59	121,117.03	38,947.66	114,603.81	47,588.87	89,861.62
Maximum	123,984.80	291,254.00	141,076.34	291,254.00	183,290.29	291,254.00
Minimum	0.00	0.00	0.00	0.00	0.00	0.00

Table A.2: Accessibility by Walk-Bus and Car: Off Peak

	30 Minutes		45 Minutes		60 Minutes	
	Walk-Bus	**Car**	**Walk-Bus**	**Car**	**Walk-Bus**	**Car**
Average	9,423.11	121,167.02	19,682.76	234,225.00	37,008.80	322,646.08
Standard Deviation	19,357.35	73,904.20	28,318.62	83,563.28	39,824.03	77,520.65
Maximum	86,325.94	274,425.39	98,293.51	401,551.31	136,687.24	401,844.00
Minimum	0.00	0.00	0.00	103.10	0.00	35,955.83

Table A.3: Accessibility by Walk-Bus and Car: Evening Peak

	30 Minutes		45 Minutes		60 Minutes	
	Walk-Bus	**Car**	**Walk-Bus**	**Car**	**Walk-Bus**	**Car**
Average	10,044.15	58,711.56	21,136.62	148,917.31	38,003.89	248,819.84
Standard Deviation	16,579.09	57,177.84	28,213.70	89,480.61	43,038.84	96,275.49
Maximum	58,712.40	218,206.80	119,142.80	352,818.36	160,038.22	449,021.64
Minimum	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B: Descriptive Statistics of Travel Behavior

*includes self-employment trips

Table B.1: Distribution of Trips by Purpose and Travel Time (All Destinations)

	Travel Time (minutes)				
Purpose	**<=30**	**30 - 60**	**60 - 90**	**>90**	**Total**
Homeward	56.4%	32.5%	9.1%	1.9%	100.0%
Work*	56.0%	28.9%	12.9%	2.2%	100.0%
School	74.0%	17.4%	7.8%	0.7%	100.0%
Non-work	60.7%	29.8%	7.9%	1.6%	100.0%

Table B.2: Distribution of trips by purpose and travel Time (Destinations other than the Major Destinations)

	Travel Time (minutes)				
Purpose	**<=30**	**30 - 60**	**60 - 90**	**>90**	**Total**
Homeward	57.2%	32.2%	8.7%	1.8%	100.0%
Work*	57.5%	28.0%	12.3%	2.2%	100.0%
School	74.6%	16.8%	7.7%	0.8%	100.0%
Non-work	63.3%	28.1%	7.2%	1.5%	100.0%

Table B.3: Distribution of Trips by Purpose and Distance (All Destinations)

	Purpose			
Distance (km)	**Homeward**	**Work***	**School**	**Non-work**
<=0.5000	32.20%	21.26%	41.77%	29.37%
0.5001-1.5000	11.80%	11.66%	17.70%	12.24%
1.5001-2.5000	14.49%	14.35%	13.28%	15.98%
2.5001-3.5000	11.24%	13.83%	8.09%	13.47%
3.5001-4.5000	8.46%	11.56%	6.20%	9.36%
4.5001-5.5000	6.72%	8.64%	4.09%	6.81%
5.5001-6.5000	4.39%	6.09%	2.67%	4.17%
>6.5000	10.70%	12.60%	6.20%	8.61%
Total	100.0%	100.0%	100.0%	100.0%

Table B.4: Distribution of Trips by Purpose and Distance (Destinations other than the Major Destinations)

	Purpose			
Distance (km)	**Homeward**	**Work***	**School**	**Non-work**
<=0.5000	31.87%	21.78%	42.33%	29.93%
0.5001-1.5000	13.20%	13.09%	18.35%	14.49%
1.5001-2.5000	14.24%	14.71%	13.30%	16.88%
2.5001-3.5000	11.25%	13.68%	7.62%	12.68%
3.5001-4.5000	8.54%	11.08%	5.95%	8.71%
4.5001-5.5000	6.42%	7.83%	3.82%	6.39%
5.5001-6.5000	4.28%	5.46%	2.48%	3.58%
>6.5000	10.19%	12.38%	6.17%	7.35%
Total	100.00%	100.00%	100.00%	100.00%

Table B.5: Distribution of Trips by Purpose and Main Mode (All Destinations)

	Purpose			
Main Mode	**Homeward**	**Work***	**School**	**Non-work**
Walking/Bicycle	22.18%	14.72%	33.07%	21.20%
Rickshaw	46.57%	38.53%	44.64%	48.76%
Public Bus	9.98%	15.46%	7.07%	8.68%
School/College Bus/Van	10.97%	16.02%	10.57%	9.81%
Motorcycle	1.54%	3.67%	0.60%	1.69%
CNG/Mishuk/Taxi/Auto Tempo	5.54%	6.14%	1.62%	6.94%
Car/Microbus/Jeep	3.09%	5.11%	2.40%	2.85%
Others	0.13%	0.33%	0.02%	0.07%
Total	100.00%	100.00%	100.00%	100.00%

Table B.6: Distribution of Trips by Purpose and Main Mode (Destinations other than the Major Destinations)

	Purpose			
Main Mode	**Homeward**	**Work***	**School**	**Non-work**
Walking/Bicycle	22.05%	15.27%	33.75%	21.78%
Rickshaw	48.22%	40.66%	44.53%	50.75%
Public Bus	9.21%	14.44%	6.73%	7.92%
School/College Bus/Van	10.81%	15.17%	10.37%	9.02%
Motorcycle	1.53%	3.52%	0.58%	1.69%
CNG/Mishuk/Taxi/Auto Tempo	5.34%	5.88%	1.64%	6.10%
Car/Microbus/Jeep	2.72%	4.69%	2.39%	2.67%
Others	0.13%	0.38%	0.02%	0.07%
Total	100.00%	100.00%	100.00%	100.00%

Table B.7: Distribution of Trips by Travel Time and Main Mode (All Destinations)

	Travel Time (minutes)			
Main Mode	**<=30**	**30-60**	**60-90**	**>90**
Walking/Bicycle	34.20%	4.10%	2.05%	2.65%
Rickshaw	51.73%	44.82%	16.47%	13.05%
Public Bus	2.87%	16.24%	32.12%	42.93%
School/College Bus/Van	5.03%	18.53%	25.76%	23.94%
Motorcycle	1.93%	1.79%	1.86%	1.30%
CNG/Mishuk/Taxi/Auto Tempo	2.07%	9.72%	14.80%	11.35%
Car/Microbus/Jeep	2.08%	4.59%	6.67%	4.47%
Others	0.08%	0.20%	0.28%	0.31%
Total	100.00%	100.00%	100.00%	100.00%

Table B.8: Distribution of Trips by Travel Time and Main Mode (Destinations other than the Major Destinations)

	Travel Time (minutes)			
Main Mode	**<=30**	**30-60**	**60-90**	**>90**
Walking/Bicycle	33.87%	4.16%	2.27%	2.66%
Rickshaw	52.66%	47.45%	17.86%	14.40%
Public Bus	2.67%	15.19%	30.93%	41.99%
School/College Bus/Van	4.85%	18.11%	26.19%	23.47%
Motorcycle	1.83%	1.79%	2.04%	1.46%
CNG/Mishuk/Taxi/Auto Tempo	2.04%	9.04%	14.47%	11.54%
Car/Microbus/Jeep	1.99%	4.05%	5.91%	4.12%
Others	0.09%	0.21%	0.34%	0.37%
Total	100.00%	100.00%	100.00%	100.00%

Table B.9: Distribution of Trips by Main Mode and Distance (All Destinations)

	Main Mode							
Distance (km)	**Walking /Bicycle**	**Rickshaw**	**Public Bus**	**School/College Bus/Van**	**Motorcycle**	**CNG/Mishuk/ Taxi/Auto Tempo**	**Car/Microbus /Jeep**	**Others**
<=0.5000	54.71%	39.30%	1.16%	1.82%	1.03%	0.95%	0.90%	0.12%
0.5001-1.5000	19.30%	71.08%	1.84%	3.08%	1.48%	1.95%	1.12%	0.15%
1.5001-2.5000	8.86%	68.38%	6.47%	8.25%	1.72%	4.01%	2.21%	0.09%
2.5001-3.5000	4.05%	60.51%	10.57%	13.87%	2.26%	5.02%	3.58%	0.14%
3.5001-4.5000	2.43%	46.02%	16.38%	18.53%	2.75%	9.28%	4.45%	0.16%
4.5001-5.5000	1.78%	28.96%	21.77%	26.47%	2.37%	11.70%	6.70%	0.24%
5.5001-6.5000	1.26%	16.97%	27.86%	27.87%	3.69%	14.44%	7.68%	0.22%
>6.5000	1.63%	8.87%	32.63%	27.95%	2.62%	17.01%	9.14%	0.15%

Table B.10: Distribution of Trips by Main Mode and Distance (Major Destinations)

	Main Mode							
Distance (km)	**Walking /Bicycle**	**Rickshaw**	**Public Bus**	**School/College Bus/Van**	**Motorcycle**	**CNG/Mishuk/ Taxi/Auto Tempo**	**Car/Microbus /Jeep**	**Others**
<=0.5000	55.23%	37.64%	1.94%	1.79%	1.80%	0.63%	0.94%	0.03%
0.5001-1.5000	19.63%	68.99%	2.54%	4.30%	1.38%	0.64%	2.51%	0.00%
1.5001-2.5000	13.06%	56.15%	11.28%	10.21%	1.10%	5.33%	2.81%	0.06%

Distance (km)	Walking /Bicycle	Rickshaw	Public Bus	School/College Bus/Van	Motorcycle	CNG/Mishuk/ Taxi/Auto Tempo	Car/Microbus /Jeep	Others
2.5001-3.5000	5.40%	57.31%	12.34%	11.39%	2.12%	5.61%	5.83%	0.00%
3.5001-4.5000	1.52%	35.70%	20.78%	20.06%	2.74%	13.49%	5.70%	0.00%
4.5001-5.5000	0.87%	16.10%	24.13%	29.62%	2.75%	17.00%	9.44%	0.08%
5.5001-6.5000	0.28%	6.42%	35.00%	27.33%	3.18%	14.70%	12.62%	0.46%
>6.5000	1.54%	7.19%	33.80%	26.71%	2.59%	17.12%	10.94%	0.11%

Table B.11: Distribution of Trips by Main Mode and Distance (Destinations other than the Major Destinations)

	Main Mode							
Distance (km)	**Walking /Bicycle**	**Rickshaw**	**Public Bus**	**School/College Bus/Van**	**Motorcycle**	**CNG/Mishuk/ Taxi/Auto Tempo**	**Car/Microbus /Jeep**	**Others**
<=0.5000	54.63%	39.56%	1.04%	1.83%	0.91%	1.00%	0.90%	0.13%
0.5001-1.5000	19.29%	71.14%	1.82%	3.04%	1.49%	1.99%	1.08%	0.15%
1.5001-2.5000	8.21%	70.26%	5.73%	7.95%	1.82%	3.81%	2.12%	0.10%
2.5001-3.5000	3.80%	61.10%	10.25%	14.33%	2.29%	4.91%	3.16%	0.16%
3.5001-4.5000	2.60%	47.96%	15.55%	18.24%	2.76%	8.49%	4.22%	0.19%
4.5001-5.5000	2.00%	31.99%	21.21%	25.73%	2.28%	10.45%	6.06%	0.28%
5.5001-6.5000	1.51%	19.55%	26.11%	28.00%	3.82%	14.38%	6.47%	0.16%
>6.5000	1.66%	9.26%	32.36%	28.24%	2.63%	16.98%	8.72%	0.16%