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Reaching Non-Work Destinations: Accessibility and Its Impacts on Travel Behavior

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REACHING NON-WORK DESTINATIONS:

ACCESSIBILITY AND ITS IMPACTS ON TRAVEL BEHAVIOR

by

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ABSTRACT

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As people's daily activities are diverse, having access to various opportunities is important. However, the existing body of accessibility literature places great emphasis on job accessibility; research on non-work accessibility is limited. To fill the gap, this dissertation examines accessibility to four types of non-work opportunities (healthcare, retail, recreation, and food services) by three transportation modes (automobile, transit, and walking) as well as their impacts on travel in the Milwaukee region.

This dissertation examines accessibility disparities across different racial/ethnic groups and income groups in Milwaukee County by comparing weighted average accessibility and overlaying spatial distribution of accessibility with population distributions. Results suggest that disparities in non-work accessibility across different sociodemographic groups exist, and the dissertation identifies the group in the most disadvantaged position.

Using structural equation models, the second part of this dissertation investigates the relationship between accessibility and travel behavior of non-work trips while controlling for neighborhood built environment characteristics, psychological factors, and socioeconomic characteristics. Results provide empirical evidence on whether accessibility affects various non-work trips differently. This dissertation finds that accessibility has significant impacts on reducing trip distance for non-work trips, and the impacts are the largest for food services,

followed by healthcare and retail, and the smallest for recreation. Additionally, improvements in accessibility to food services and recreational facilities encourage non-work travel for respective trips.

Findings of this dissertation have policy implications. The multi-modal accessibility indicators contribute to a comprehensive understanding of disparities in accessibility and inform planning research and practice about spatial gaps in both goods/service supply and transportation services. Additionally, the empirical analysis of the accessibility effect on travel can inform targeted mobility or land use strategies.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACS	American Community Survey
EPA	Environmental Protection Agency
LODES	Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics
LEHD	Longitudinal Employer-Household Dynamics
MCTS	Milwaukee County Transit System
NAICS	North American Industry Classification System
NHTS	National Household Travel Survey
SEM	Structural Equation Modeling
SES	Socioeconomic Status
SEWRPC	Southeastern Wisconsin Regional Planning Commission
SLD	Smart Location Database
VMT	Vehicle Miles Traveled

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Chapter 1. Introduction

1.1. Research Background

The idea of accessibility emerged in the 1950s. It denotes the ease of reaching potential opportunities (Hansen, 1959), which is commonly conceptualized as affected by two elements: land use element and transportation element (Burns, 1979; Koening, 1980). The land use element represents the spatial distribution of potential opportunities and is often measured by the number of opportunities at destinations, such as the number of employment/employees and the floor space of buildings (Handy & Clifton, 2001). The transportation element refers to the ease of traveling to potential opportunities. Travel time and distance as well as monetary cost are common indicators. As land use and transportation system jointly determine people's access to desired destinations, examining accessibility allows researchers to assess the spatial distribution of opportunities and the efficiency of transportation networks, and subsequently contribute to developing policy interventions.

Accessibility is of great significance in transportation planning. On the one hand, it contributes to the wellbeing of individuals. Unlike traditional mobility-based transportation planning that may result in sprawling urban patterns and long-distance trips, accessibility-based transportation planning aims to reduce the spatial separation between origins and various opportunities and enables the public to receive fundamental services and goods easily. On the other hand, accessibility tends to be socially inclusive. In other words, those who cannot afford automobile travel could still have great accessibility. For example, land-use strategies, such as compact or mixed-use development, improve accessibility by promoting proximity, and thus people who do not afford automobile trips are able to fulfill their needs at nearby locations. Mobility solutions, such as transit network expansion and discounted car rides, are intended to reduce travel barriers, helping transportation-disadvantaged groups (e.g., autoless or low-income) reach distant opportunities.

Literature on accessibility has vastly accumulated since the 1970s (Handy, 2020). However, the existing body of literature places great emphasis on job accessibility. Much research has discussed the effects of spatial access to potential job opportunities on employment outcomes of job seekers and their commuting duration or distance if employed (e.g., Boussauw et al., 2012; He et al., 2020; Hu, 2017; Ihlanfeldt, 1993; Kawabata, 2003; Kawabata & Shen, 2007; Levinson, 1998; Peng, 1997; Qin & Wang, 2019; Sultana, 2002; B. Sun et al., 2016). The findings inform policymakers to reduce the spatial separation between job seekers and employment, which would benefit those in the labor force.

Having access to non-work opportunities is also important to individuals' wellbeing. People need to visit non-work destinations (e.g., restaurants, hospitals, and stores) to obtain fundamental services and goods (Hanson and Giuliano, 2004, p.3). Retail stores, restaurants, recreation facilities, and healthcare are essential services. According to National Household Travel Survey conducted in 2001, 2009, and 2017, the percentage of personal trips to these four types of destinations stayed stable at 75% to 80%, with shopping and recreation trips accounting for the largest share and followed by dining and seeking healthcare (McGuckin & Fucci, 2018). In other words, access to these non-work opportunities can significantly influence travel patterns. Nevertheless, literature on this type of accessibility is scarce. A small number of studies have touched upon the topic: only a few studies include multiple non-work opportunities in the analysis (Chen & Wang, 2020; Greng, 2015), and some others examine accessibility to a single type of non-work opportunities (e.g., Ekkel & de Vries, 2017; Song et al., 2018; L. Wang & Lo, 2007).

Moreover, it is necessary to examine the access to non-work opportunities by multiple transportation modes. Having access to non-work destinations by automobile is essential because automobile is the main transportation mode that most people rely on for daily trips in the U.S. Access to non-work opportunities by non-automobile travel mode is equally important, as many non-work trips are short-distance and have some spatial-temporal flexibility. However, existing research usually measures accessibility by automobile (Bejleri et al., 2017; Niedzielski, 2021) and/or transit (Niedzielski, 2021; Widener et al., 2015). It is possible that some neighborhoods have great accessibility by automobiles but poor accessibility by other transportation modes such as transit, bicycling, and walking, or vice-versa. To my knowledge, few studies have examined accessibility by multiple transportation modes, especially non-automobile modes.

Furthermore, the relationship between accessibility and travel behavior of non-work trips deserves research attention. Land use strategies such as mixed-use and high-density development aim to improve accessibility to diverse opportunities. However, few studies have comprehensively investigated the impacts of accessibility to diverse non-work opportunities on travel behavior of non-work trips, which is the premise of implementing accessibility-based strategies towards non-work opportunities.

1.2. Research Statement

To fill these gaps, this dissertation investigates accessibility to four types of non-work opportunities (healthcare, retail, recreation, and food services) by three transportation modes (automobile, transit, and walking) as well as their impacts on travel in the Milwaukee region.

1.2.1. Research Questions and Hypotheses

This dissertation aims to answer two questions. **First, are there disparities in accessibility to non-work opportunities across different sociodemographic groups? Second, how does access to various opportunities affect travel to these opportunities?**

Answers to these two questions have planning and policy implications. Understanding the disparities in non-work accessibility across different population groups can guide land use and transportation investment. Besides, the effects of accessibility to non-work opportunities on travel lends support to implementing accessibility-based policies toward comprehensive consideration of non-work activities, which would bring broad social and environmental benefits. Thus, results of this dissertation inform planning research and practice about spatial gaps in both goods/service supply and transportation services.

To answer the research questions, this dissertation proposes two hypotheses. First, disparities in non-work accessibility exist. Much literature suggests that due to limited resources, the allocations of various opportunities and transportation services are uneven. Consequently, disparities in non-work accessibility might exist among populations of different sociodemographic characteristics because of the uneven distribution of home locations for these population groups. This dissertation delineates a multi-facet picture of non-work accessibility disparities by comparing the differences in accessibility to the four types of opportunities by three transportation modes across different population groups.

Second, the effects of accessibility on travel vary by the types of opportunities. Theories suggest that travel is derived, and therefore people care about travel costs and want to minimize costs to maximize the utility at destinations. Accessibility is expected to affect travel behavior because it is closely related to travel costs. As there are a variety of trip purposes, people's sensitivity to travel costs is unlikely to be the same. This dissertation will provide empirical evidence on whether accessibility affects various non-work trips differently.

1.2.2. Study Area, Data, and Methodology

The seven-county region in Southeast Wisconsin is selected as the study area. This dissertation focuses on the travel behavior of residents in the central county of the region, Milwaukee County. Milwaukee County has a notable portion of the disadvantaged population who may encounter travel difficulties. Note that accessibility is measured at the regional level since some Milwaukee County residents still need to travel to non-work destinations outside of the County.

Data come from five sources: (1) the employment data from the 2017 Longitudinal Employer-Household Dynamics (LEHD); (2) centroid-to-centroid interzonal travel time from Google Maps; (3) the 2017 National Household Travel Survey (NHTS) WI add-on dataset, which recorded travelers' demographic and socioeconomic characteristics as well as detailed trip information; (4) the 2021 Smart Location Database (SLD) provides the built environment data; (5) 2018 American Community Survey (ACS) 5-year estimate gives demographic information of census tracts.

To calculate accessibility, I used employment data reported at the workplace as the proxy for non-work activity opportunities and travel time matrices of automobile, transit, and walking retrieved from Google Maps. This dissertation measures gravity-based accessibility to non-work opportunities in the seven-county region of Southeast Wisconsin. This dissertation examines accessibility disparities across different racial/ethnic groups and income groups in Milwaukee County by comparing weighted average accessibility and overlaying spatial distribution of accessibility with population distributions.

This dissertation investigates the effects of accessibility to four types of non-work opportunities on two indicators of travel behavior: travel distance and travel mode (non-auto travel or not). The examination of accessibility effects relies on two types of data: the accessibility measurement calculated in this dissertation and trip information from the 2017 National Household Travel Survey (NHTS) WI add-on. This dissertation applies structural equation models to examine the causal relationship between accessibility and travel while controlling for neighborhood built environment characteristics, psychological factors, and socioeconomic characteristics on travel behavior.

Empirical results support the hypothesis of research question 1. Disparities in non-work accessibility across different sociodemographic groups exist, and the dissertation identifies the group in the most disadvantaged position. Generally, disadvantaged groups have better non-work accessibility to all four types of opportunities by both automobile and non-automobile modes than their counterparts. However, differences are observed in accessibility within the same racial/ethnic groups, and it is likely that lower-income groups encounter environmental injustice although having high automobile-based accessibility.

Answers to research question 2 are nuanced. Results indicate that accessibility has significant impacts on reducing trip distance for non-work trips, and the impacts are the largest for food services, followed by healthcare and retail, and the smallest for recreation. Additionally, results show that improvements in accessibility to food services and recreation encourage non-work travel, whereas increases in accessibility to healthcare and retail do not show significant impacts.

1.3. Contributions

The dissertation provides new empirical knowledge to the field. First, the multi-modal accessibility indicators contribute to a comprehensive understanding of disparities in non-work accessibility across different sociodemographic groups. Second, separately investigating causal relationships between accessibility and travel behavior of specific non-work trips can inform targeted mobility or land use strategies.

These findings have policy implications. Although racial/ethnic minorities generally have better accessibility, such appeared spatial advantages can be the results of discriminative behavior in the housing market and in business location decisions. Additionally, we need to consider in-group differences in non-work accessibility and focus on minority neighborhoods whose accessibility is below the average of the same minority groups. As environmental injustice may exist in lower-income communities, planning needs to develop strategies to reduce their exposure to pollution and noise.

Furthermore, this dissertation lends support to the implementation of accessibility-based planning that considers non-work activities. As accessibility to restaurants affects individuals' travel to food to a greater extent than other trip purposes, land use and transportation planning that considers increasing accessibility to restaurants and food-related opportunities can effectively reduce travel and related negative externalities. The inelastic result of healthcare accessibility suggests the importance of providing automobile travel for healthcare trips.

1.4. Organization of the Dissertation

The remaining of this dissertation is organized as follows. Chapter 2 reviews literature on non-work accessibility, general knowledge of travel behavior, and the relationship between accessibility and travel. Chapter 3 introduces the study area and describes data and methodology applied in this dissertation. Chapter 4 and Chapter 5 provide research results to test the first and second hypothesis, respectively. Chapter 6 summarizes findings and provides a discussion on policy and planning implications, limitations of this research, and potential research directions in the future.

Chapter 2. Literature Review

2.1. Non-work Accessibility

2.1.1. Accessibility to Non-work Opportunities

Accessibility measures the ease of reaching opportunities (Hansen, 1959). Individuals living in places of high accessibility can easily reach opportunities in question and hence are likely to meet their social and economic needs (Handy & Niemeier, 1997). As land use and transportation system jointly determine people's access to desired destinations (Handy & Niemeier, 1997), examining accessibility allows researchers to assess the spatial distribution of opportunities and the efficiency of transportation networks. Research on accessibility can contribute to developing policy interventions, informing planners to optimize land use or improve transportation services.

As employment is closely associated with individuals' economic prospects, a large stream of literature focuses on job accessibility (Debrezion et al., 2007; Easley, 2018; Grisé et al., 2019; Hu, 2015b; Hu et al., 2017; Ihlanfeldt & Sjoquist, 1990; Kawabata, 2003). Some researchers shift the perspective of analysis from job seekers to job providers, examining the employee accessibility of employers (Martín-Barroso et al., 2017; Sun & Hu, 2020). Overall, these studies capture the spatial separation and the (lack of) transportation connections to overcome the separation between the locations of potential job opportunities and the residences of potential employees.

Non-work accessibility, i.e., access to non-work destinations, is also important. First, all people need to visit non-work destinations (e.g., restaurants, hospitals, and stores) to obtain fundamental services and goods (Hanson and Giuliano, 2004, p.3). Moreover, having access to entertainment facilities, such as museums and stadiums, contributes to a balanced life between work and leisure (Florida, 2002). According to National Household Travel Survey conducted in

2001, 2009, and 2017, the percentage of personal trips to non-work destinations was stable at 75% to 80% (McGuckin & Fucci, 2018). An increasing amount of research investigates accessibility to non-work destinations, including healthcare facilities (Luo & Wang, 2003; Song et al., 2018), public libraries (Park, 2012), shopping malls (Wang & Lo, 2007; Widener et al., 2015), and green space (Ekkel & de Vries, 2017; Nesbitt et al., 2019).

As people's daily activities are diverse, examining accessibility to non-work opportunities facilitates a comprehensive understanding of service deliveries and helps identify spatial gaps in goods/service supply. However, little research has examined accessibility to multiple types of non-work destinations. One exception is Chen and Wang (2020)'s work, which compares transit- and bicycle-based accessibility to several types of urban opportunities (e.g., restaurants, churches, and libraries) in two medium-sized U.S. cities. They found that transit does not improve accessibility to most types of opportunities efficiently as bicycling does when traveling from city centers to suburbs. This suggests inadequate service coverage of local transit systems.

My dissertation will measure accessibility to four non-work destinations: retail stores, restaurants, recreation facilities, and healthcare. These four categories indicate essential services for people's wellbeing and quality of life, and they are major destinations of nonwork trips. Shopping trips and recreational trips, although continued to decline from 2009 with online shopping and telecommunications gaining popularity, still accounted for a major share of nonwork travel, which was 38.4% in 2017 (McGuckin & Fucci, 2018). Lifestyle changes such as reducing home cooking induce frequent trips to restaurants (Robson et al., 2016). Clinics and the outpatient department of hospitals remain as the major sources of health advice and basic medical treatments. It has been reported that the visits to nurse practitioners and physician assistants increased by129% from 2012 to 2016, partially offsetting the nationwide drop in visits to primary care physicians over the past decade (Frost & Hargraves, 2018).

2.1.2. Locations of Different Industries

This dissertation focuses on four types of opportunities: healthcare, recreation, food services, and retail trade. The locational distributions of the four types of opportunities are different, which would influence the patterns of non-work accessibility. For each industry, location decisions are made based on the trade-offs between a variety of factors, such as land rent, transportation costs, proximity to the market, etc. Classic urban economic theories suggest that industries finally choose the locations that enable them to maximize profits. This section discusses the common locations of these four industries and key factors that influence their location decisions.

Recreation opportunities are often situated in the city with convenient locations and transportation because facilities like museums and stadiums tend to serve the whole region. Besides, a key benefit of locating in city is agglomeration economies (Giuliano and Small, 1999). Specifically, there are various opportunities in the city. Those who visit other types of opportunities are potential customers of recreational facilities.

The food service industry, e.g., restaurants, is market-oriented and thus tends to locate in the city, which is a large market because of agglomeration economies. Further, based on Hotelling (1929)'s model, restaurants are likely to be clustered on certain streets to share customers. In particular, those sell similar food tend to locate next to each other, competing and sharing customers.

Healthcare services are also sensitive to agglomeration economies. As knowledge, workforce or talents, and services can be shared through co-location (Giuliano & Small, 1999), healthcare services are likely to co-locate with other industries such as educational institutions and technology companies in the central location, such as in the city, to facilitate interactions and cooperations. However, a challenge of locating in the city is land scarcity and associated high land rents (Giuliano & Small, 1999). Healthcare services may also consider places with sufficient space and relatively lower land values, such as suburbs, because hospitals or medical research centers need large space to accommodate patients, labs, treatment facilities etc. Similarly, retail trade that sells home furniture, appliance, electronics, clothing, and grocery is also land-intensive. It needs a large amount of land for storage and display. Besides, retail stores are also inclined to places that are proximate to potential market (O' Sullivan, 1993). As population grows rapidly in suburbs, retail stores tend to locate at suburban areas where both have land and customers.

2.1.3. Accessibility Measurement

In theory, accessibility is comprised of two basic elements, activity element and transportation element (Burns, 1979; Koening, 1980). The activity element represents the spatial distribution of potential opportunities. It is often measured by the number of opportunities at destinations, such as the number of employment/employees and the floor space of buildings (Handy & Clifton, 2001). The transportation element refers to the ease of traveling to potential opportunities. It reflects the availability of transit services, travel time/distance, and monetary cost of traveling (Handy & Clifton, 2001).

The measurements of accessibility have improved as researchers enhanced their understanding of the concept. The simplest proxy for accessibility is travel time/distance, which is prevalent in early studies (Ellwood, 1986; Ihlanfeldt & Sjoquist, 1990). However, observed travel time/distance is the outcome of those who make these trips but overlook people who have no access to opportunities and thus cannot travel to desired destinations. Besides, spatial and aspatial factors both influence observed travel time, and hence, using outcomes that result from mixed factors to guide spatial planning, e.g., land use and transportation, would be problematic (Hu, 2017).

Other common indicators are cumulative opportunity and gravity-based, incorporating travel time and the number of opportunities in measurements (Handy & Niemeier, 1997). A major difference is that cumulative opportunity treats every opportunity equally while the gravity-based weights each of them by travel time or distance. Considering the competition for potential opportunities, Shen (1998) developed a relative gravity-based accessibility measure on the basis of the conventional one, which discounts the supply of opportunities by both travel impedance and demands. Besides that, measures that include both the supply and demand sides can be calculated by the doubly-constrained spatial model (Wilson, 1970) and the two-step floating catchment (2SFCA) method (Luo & Wang, 2003).

Among all accessibility measures, the conventional gravity-based is the most suitable one for examining accessibility to non-work destinations. People are likely to find distant opportunities less attractive than closer ones due to travel burden, and this behavior is well reflected by the travel impedance function of gravity-based measures (Merlin & Hu, 2017). Additionally, Handy and Niemeier (1997) suggested that gravity-based measures allow disaggregation by transportation modes. Compared to Shen’s relative accessibility, the conventional, i.e., non-competitive, measure is more appropriate. The flow of people at non-work destinations largely weakens the competition for goods or services (Horner and O’Kelly, 2007), and mathematically, it is difficult to estimate demands even for non-work destinations that require appointments because many of them accept walk-in customers as well. For the above reasons, my dissertation adopts the conventional gravity-based measure to measure accessibility to non-work destinations by three transportation modes, automobile, transit, and walking.

2.1.4. Disparities in Non-work Accessibility

It is crucial to scrutinize the disparities in accessibility through the lens of equity. The consequence of inequality in accessibility is severe. People living in places with poor accessibility tend to pay expensive travel costs, which is likely to constrain their participation in various social activities and interactions (Allen & Farber, 2019), and gradually they are in danger of being excluded by society (Pereira et al., 2017). My dissertation is intended to explore the disparities in accessibility to non-work opportunities across different population groups. Current literature suggests that disparities in non-work accessibility are likely to exist across different population groups, particularly between those who are potentially disadvantaged, such as racial/ethnic minorities and lower-income groups, and their advantaged counterparts. Uneven allocation of services and differences in transportation mobility tend to be the causes for such disparities.

From the perspective of land use, places of concentrations of disadvantaged populations, i.e., disadvantaged neighborhoods, are likely to have fewer non-work opportunities. Following population suburbanization, a lot of service or goods suppliers began to expand their business in suburbs in the1960s (Hanson and Giuliano, 2004, p.80). Yet, the expansion quickly turned into suburbanization in many metropolitan areas (Hanson and Giuliano, 2004, p.81). Take Philadelphia as an example, above 80% of opportunities in wholesale and retail trade completely relocated to suburbs in 1998 (Hanson and Giuliano, 2004, p.82). The suburbanized rate of health and finance services was relatively modest but still accounted for more than 60% (Hanson and Giuliano, 2004, p.82). The suburbanization of service sectors undoubtedly reduced the number of opportunities in city, and in this process, disadvantaged neighborhoods are vulnerable. Lineberry (1975)'s Underclass Hypothesis states that the quantity and quality of services in disadvantaged neighborhoods are inferior compared to others. Indeed, much empirical research has documented that places with inadequate green space (Hoffimann et al., 2017; Rigolon, 2017) and healthy food (Kuai & Zhao, 2017) are disproportionally socially disadvantaged communities.

Moreover, people with distinct socioeconomic status tend to have different levels of mobility. Automobile travel indicates high levels of mobility and is prevalent among people of higher socioeconomic status (SES), whereas people with lower socioeconomic status may have financial hardship and are likely to experience difficulties in affording vehicles and making long-distance travel. Instead, they need to rely on other transportation modes, such as public transit (Clifton & Handy, 2001), which is slower and has fixed routes and operation hours.

The demands for public transportation constrain disadvantaged groups in neighborhoods that are served by transit systems (Cao et al., 2009), and hence, places with clusters of lower SES groups commonly have good transit mobility. By contrast, people of higher SES are often less transit-dependent and thus the neighborhoods they concentrate generally have limited transit services. Nevertheless, transit services in higher SES neighborhoods are not always inferior compared to their lower SES counterparts. Studies have revealed that the development of rapid transit, such as rails and express buses, can increase property values near stations (Debrezion et al., 2007), which may attract the middle class but price out low-income residents (Dawkins & Moeckel, 2016). In this case, gentrified neighborhoods, which have a growing number of higher SES residents, have higher levels of transit mobility.

Likewise, neighborhood walkability varies in city and tends to be associated with socioeconomic composition. Evidence from Buffalo, NY, and Charlotte, NC has shown that block groups with a concentration of disadvantaged population (e.g., minorities, poor, low-education) are more likely to have unwalkable street features, such as long block length, fewer street nodes (Bereitschaft, 2017; Knight et al., 2018). Poor walkability may reduce people's desire for walking and is likely to increase walking time more or less.

Some studies have compared accessibility with respect to socioeconomic characteristics, but results are mixed. Diao (2014) confirmed that deprived communities in the Boston metropolitan region are underserved, with lower food accessibility than wealthier areas, whereas Dai and Wang (2011)'s work showed that in Mississippi, US, populations of lower socioeconomic status tend to have good spatial access to food retailers. Allen and Farber (2019) found that low-income neighborhoods in Canada's major cities generally have advantages in terms of accessibility, but they also suggested that the number of low-income people who have poor access to social opportunities is still considerably large, which needs policymakers' attention.

The locational advantage of the inner city and the residential locations of lower SES groups can explain the overall advantage of lower SES neighborhoods in accessibility. Although service sectors suburbanized substantially, it is found that the distribution of service-related opportunities was dispersed (Heider & Siedentop, 2020), which means suburban residents have to travel a long distance to access some opportunities. By contrast, opportunities that remained in city are relatively clustered; therefore, in general, the inner city still has advantage in terms of accessibility. For better environment and living conditions, wealthy households tend to move to low-density suburbs at the expense of good accessibility, while those who have relatively low socioeconomic status remain in the inner city and continue to enjoy good access to various opportunities (Mieszkowski & Mills, 1993). In this sense, the urban-suburban differences tend to mask the disparity between the lower SES and higher SES population groups. As Allen and Farber (2019)'s work suggests, comparing accessibility with respect to socioeconomic status at the regional level is likely to overestimate the situation of disadvantaged groups.

Therefore, one research question that this dissertation aims to answer is: are there disparities in accessibility to non-job opportunities? Answers to this question advance the research area in two ways. First, examining disparities in non-work accessibility in an urban context reduces errors caused by urban-suburban differences. Second, accessibility by multiple non-automobile modes is examined. A variety of transportation options are available in urban areas, and city residents, especially those who cannot afford automobile travel, are likely to rely on more than one type of non-automobile modes. Therefore, in addition to accessibility by automobile, this dissertation also examines accessibility to non-work destinations by two essential non-auto modes in urban areas, transit and walking, respectively.

2.2. Non-work Accessibility and Travel Behavior

This section first presents general knowledge of travel, including theories that have been widely applied to explain personal travel and factors that affect specific travel behavior. Then, it summarizes literature on the relationship between accessibility and travel.

2.2.1. Travel Behavior

The traditional theoretical foundations that explain travel behavior are the utility maximization theory and the notion of "travel is a derived demand". Utility represents the level of satisfaction, which is originally a term in economics. Utility maximization means that individuals and firms try to make economic decisions that enable them to achieve the highest level of satisfaction and benefits. The activities at destinations are associated with a certain level of utility. "Travel is a derived demand" was first put forward by Mitchell and Rapkin (1954).

The notion argues that the desire for movements derives from the demand for reaching certain places, such as retail stores, restaurants, and parks. The activities at these places, i.e., attractiveness, can meet people's various needs thus motivate them to travel. As travel is derived under most circumstances, people would like to reduce the cost of trips thereby maximizing their utility at destinations.

Travel behavior can be measured in a variety of ways, including trip generation, trip frequency, trip cost, travel distance, travel time, travel mode, route choice, departure time, travel companion, etc. For non-work travel, this dissertation will focus on trip frequency, trip distance, and trip mode, because these three indicators are more commonly used in travel behavior research than others.

Factors that shape travel behavior are multifaceted, including land use patterns, transportation services, socioeconomic characteristics, and psychological variables.
First, land use patterns influence travel at two scales: the macroscale and the microscale. At the macroscale, spatial structure reflects the regional distribution of population and activities, thereby influencing travel patterns like trip length and trip direction. Historically, metropolitan areas are monocentric: employment and various social opportunities tend to be centralized (Handy and Niemeir, 1997). Inner-city residents can enjoy the proximity to opportunities, and thus are likely to take short-distance trips. Those who reside in peripheral areas often travel to the central city to work and conduct other activities. Nevertheless, an increasing number of metropolitan areas became polycentric and sprawling. Many inner-city residents move to suburbs and locate dispersedly (Mieszkowski and Mills,1993), and job opportunities also grew dramatically in suburban areas when the economic base shifted from manufacturing industries to service sectors. In such polycentric regions, reverse commuting becomes common among

workers who live in cities and work in suburbs (Cervero & Landis, 1992). Suburban residents are proximate to some opportunities located in suburbs and hence tend to have short trips (Gordon, et al., 1989). But they may endure long-distance travel to reach opportunities since sprawling land use enlarges the spatial separation between their residences and activity sites (Lee et al., 2009). This dissertation uses the spatial distribution of non-work opportunities, which captures land use patterns at the macro level, in the job accessibility measure.

The built environment characteristics affect travel at the microscale. Cervero and Kockelman (1997) identified three D variables: density, diversity, and design. Density and diversity demonstrate the degree of spatial separation/proximity between origins and potential destinations at the neighborhood level. In areas with high density and mixed land-use, such as traditional neighborhoods with commercial streets, different types of activity sites, such as restaurants and groceries, are located closer to residences. The pattern enables residents to carry out various activities within short distance and potentially influences their choice of trip mode (Limanond & Niemeier, 2004; Clark et al., 2016). Design tends to influence travel behavior in a different way. People are likely to conduct certain travel behavior when design features create a favorable environment for them to do so. For instance, neighborhoods with good street connectivity and appropriate sidewalk width are pedestrian-friendly, and therefore attract people to walk (Ewing & Cervero, 2010). The accessibility measurement in this dissertation does not reflect the above built environment characteristics. Instead, this dissertation uses these features as control variables in analysis.

In addition to the original three Ds, more D variables are used to describe built environment, and destination accessibility is one of them. It can be simply measured as the distance to the closet destination or the number of opportunities can be reached within certain time (Ewing & Cervero, 2010). Similar to the concept of accessibility defined in this dissertation, destination accessibility also shows distance decay: accessibility decreases as the distance from the origin increases (Ewing & Cervero, 2010), but the difference is that destination accessibility does not consider transportation factors such as the availability of transportation services.

In summary, land use patterns at both the macro- and the micro-scale are associated with the potential choices of destinations. More reachable destinations contribute to higher levels of accessibility (Handy and Niemeir, 1997). But great accessibility does not necessarily result from the spatial pattern of opportunities. Transportation between origins and destinations also plays a vital role in accessibility but is neglected in land use patterns (Handy and Niemeir, 1997).

Second, transportation services impact individuals' travel patterns. Regional and city-wide transportation network connects residential neighborhoods with various urban and suburban opportunities. The routes and operation hours of many public transportation systems are fixed, which would affect transit riders' travel behavior, such as departure time and travel routes. Additionally, lack of transportation options prevents people from making trips to reach desired opportunities. For example, without reliable regional transit, many autoless inner-city job seekers are constrained in urban areas and segregated from suburban job opportunities (Kain, 1968). Similarly, the unavailability of private vehicle and transit services are also barriers for visiting non-work activity sites (Kuai & Zhao, 2017), and it is found that the expansion of transit network can significantly remedy this situation (Abel & Faust, 2018).

Third, sociodemographic characteristics have pronounced effects on travel. Previous studies have observed that individuals with distinct identity tend to show different travel behavior (De Witte et al., 2013; Renne & Bennett, 2014). In many cases, men are the breadwinners, so they usually take the car, if there is one in the family, to get to workplaces and tend to have long commute distance (Goddard et al., 2006). By contrast, women are more likely to depend on buses and walking when performing errands and chauffeuring children (Miralles-Guasch et al., 2016). Their maintenance trips are often short and chained with work trips (Crane, 2007; Rosenbloom, 2004). Among all racial/ethnic groups, whites tend to be the most automobile-dependent while African Americans show the greatest reliance on public transit (Renne & Bennett, 2014). Hispanics and Asians commonly prefer automobile travel but are likely to carpool with friends and neighbors (Shin, 2017), and their trips tend to be made within or nearby ethnic enclaves (Liu & Painter, 2012).

In addition to social identity, socioeconomic characteristics also play an important role in travel behavior. People usually travel with family members for shopping and recreational activities, and large families tend to be inclined to travel by automobiles (De Witte et al., 2013). The ownership of private transportation means, such as automobile and bicycle, is found to be an important factor for choosing automobile travel and bicycling (Van Acker and Witlox, 2010; Handy et al., 2010). Work pattern also matters. Compared to on-site workers, telecommuters tend to make more trips, including both total trips and maintenance trips (He and Hu, 2015). Meanwhile, telecommuters have greater flexibility on departure time and travel routes (He, 2013).

Fourth, psychological factors (e.g., perception, attitudes, and habits) impact travel. Perceived behavior control, which indicates people's perception of whether their ability allows them to perform a certain action, tends to influence one's actual behavior (Ajzen, 1991). Schneider (2013) found that traffic accidents happened on friends and news about bicycle-related injuries caused by collisions with motor vehicles enable interviewees to feel anxious about bicycling. Consequently, speeding cars are likely to lower individuals' perceived control. Indeed, many interviewees claimed that automobile traffic prevented them from bicycling, and they prefer bicycling in a safer environment, such as streets with separated bike lanes (Schneider, 2013).

Moreover, attitudes affect travel behavior. People tend to have positive attitudes toward behaviors that provide them with physical, emotional, or other types of benefits (Ajzen, 1991). Those who care about the environment and personal health are generally fond of walking and bicycling because these nonmotorized transportation modes do not rely on fossil fuel and involve high levels of physical activities (Manaugh & El-Geneidy, 2013). Empirical evidence confirms that the disparities in attitudes can explain the differences in travel: the total walking distance of individuals with positive reactions to pedestrian travel tends to be longer than those who have neutral or negative attitudes, and similar results are yielded for bicycling (Manaugh & El-Geneidy, 2013).

Additionally, personal travel habit is a significant predictor for future travel behavior. People who frequently rely on certain transportation modes tend to develop the choice into a travel habit. (Verplanken et al., 1994). Studies suggested that the probability of choose driving for short-distance trips is higher among habitual drivers than those who only drive occasionally, even though there are other possible options like walking and bicycling (Kim & Ulfarsson, 2008). But habit is not unchangeable. The occurrence of life events (e.g., retirement and having children) may encourage people to break previous travel habits and develop a new one that fits their current situation (Bamberg, 2006).

2.2.2. Accessibility and Travel Behavior

Accessibility matters in shaping travel behavior. Accessibility integrates two important factors that influence travel: land use and transportation, and thus has impacts on travel behavior.

In addition, the effects of accessibility on travel have theoretical foundations. Given the derived nature of travel, people care about travel costs and want to minimize costs. Accessibility is closely related to travel costs because higher accessibility allows fewer spatial barriers for ones to overcome (Handy and Niemeier, 1997), which would reduce both tangible (e.g., fare, gasoline) and intangible costs (time, energy); and travel costs can influence trip decisions, such as frequency and travel mode (Button, 2010, p.80).

The association between job accessibility and commutes has drawn great attention from scholars and becomes a large stream in the accessibility research field as literature accumulates. Research that explores the effects of job accessibility on commutes yields mixed results. Many studies suggest that higher job accessibility is associated with shorter commutes (Boussauw et al., 2012; He et al., 2020; Hu, 2015a; Kawabata & Shen, 2007; Levinson, 1998; Qin & Wang, 2019; Sultana, 2002; Sun et al., 2016), encouraging the use of multiple transportation modes other than automobile (Moniruzzaman & Páez, 2012; Owen & Levinson, 2015). The association is particularly strong for the low-income group (Cui et al., 2020). Meanwhile, the stability of transit accessibility matters. Lower variation in transit accessibility within peak hours would yield more transit ridership (Owen & Levinson, 2015). A few empirical studies found very weak impacts of job accessibility on commutes, making long-distance automobile travel inevitable. Peng (1997) argued that a slight decline in Vehicle Miles Traveled (VMT) occurs only when the jobs-housing ratio falls into certain thresholds; otherwise, VMT remains unchanged. Similarly, Giuliano and Small (1993) reported a limited association in greater Los Angeles but not in downtown where the extreme jobs-housing imbalance results in long commutes. Researchers attribute the lack of consensus to residential decisions. Factors like housing affordability and double-worker families may affect location choice and thus weaken the connection between jobs and residences (Watts, 2009).

Although non-work accessibility and non-work travel received little research attention, existing literature indicates that accessibility to non-work opportunities can affect non-work travel as well. Take shopping activities as an example. Under most circumstances, people shop for convenience goods, the items that meet basic needs and are purchased regularly (Holton, 1958). With the purchase frequency in mind, shoppers would be inclined to reduce travel costs (both monetary and time costs) for every single trip to maximize utilities; and high accessibility to stores would help to achieve such goal since it enables people to choose a store with the least travel costs from abundant choices. A key assumption of the traditional retail site selection model is that store location and related travel costs are primary determinants for shopping behavior (Huff, 1964). The above hypothesis is also applicable to trips for meals, recreational, and medical purposes, which are essential types of out-of-home activities and are expected to be sensitive to travel costs.

Further, the effects of accessibility on travel should vary by the types of opportunities. Travel demand is derived, and thus sensitive to the changes in travel costs, but the price elasticity is not identical for all types of trips (Button, 2010, p.85). The types of activities and the number of substitutes for potential destinations tend to influence people's intention on whether or not to reduce travel costs to achieve maximum utility. Specifically, trips that accomplish basic demands and have greater flexibility of destination choice show high price elasticity (Button, 2010, p.85). That is, when people do daily or weekly routine activities and can readily find a substitute for the same type of services, they will pay special attention to travel costs and choose the destination with the least travel costs to maximize utility. Accordingly, accessibility to this type of opportunity has remarkable effects on corresponding trips. Trips are inelastic to cost if travel costs are negligible compared to the great value of activities at destinations and there are no close substitutes for destinations (Button, 2010, p.82). In this case, people usually do not seek for minimizing travel costs, and hence accessibility has little impact on travel.

Understanding the effects of accessibility to non-work opportunities on non-work travel is of great significance. The share of non-work trips is large and increasing. In the U.S., the share of trips for non-employment purposes accounts for 70 to 80 percent over the past decades (McGuckin & Fucci, 2018). Telecommuting reduces commutes but tends to induce more errands and recreational trips (Kim et al., 2015). Long-distance travel and excessive automobile trips tend to be detrimental to individuals' wellbeing and the environment. If the association between accessibility and travel exists in non-work trips, enhancing access to various non-work opportunities would be a promising strategy to improve personal life satisfaction and mitigate travel-related environmental externalities.

Empirical studies that probe the effects of accessibility on non-work trips are scarce, let alone the differences in the effects of accessibility to various opportunities on travel behavior. Therefore, my dissertation will examine and compare the effects of accessibility to four types of non-work opportunities (retail stores, restaurants, recreation facilities, and health care) on two indicators of travel behavior (trip distance and trip mode).

2.2.3. Methods for Modeling the Effects of Accessibility

Regression analysis is a common approach in the literature to examine the effects of accessibility. Linear regression models using either Ordinary Least Squares or Maximum Likelihood method are used when dependent variables are continuous. A lot of studies rely on simple linear models to estimate the effects of accessibility on travel time or distance (Hu, 2017;

Levinson, 1998; Shen, 2000). In some cases, closer geographic units have similar characteristics. This phenomenon is termed spatial autocorrelation and can be problematic in regression analysis. Researchers have employed spatial regression models, spatial lag or spatial error, to address the issue (Hu, 2015a; Kawabata & Shen, 2007). If dependent variables are categorical, logistic regression models are chosen. For instance, binominal and multinomial logit models have been widely applied to predict labor market outcomes (Kawabata, 2003; Korsu & Wenglenski, 2010) and commute mode share (Moniruzzaman & Páez, 2012; Owen & Levinson, 2015).

A challenge of modeling the effects of accessibility is residential endogeneity. Typically, household income and preferences influence residential decisions (Button, 2010, p.51). Specifically, households determine their residences to maximize residential utility within budget constraints (Alonso, 1964; Mills, 1967; McFadden, 1974). That is, residential locations are self-selected and thus can be endogenous with many household or personal socioeconomic characteristics and activities, including travel.

It is widely acknowledged that ignoring residential self-selection would overestimate the effects of accessibility (Cao et al., 2009; Ihlanfeldt & Sjoquist, 1990). For example, vehicle ownership can affect residential locations (Hanson and Giuliano, 2004, p.11). Households with automobiles tend to move to suburbs. Those who cannot afford automobiles and have to rely on non-auto transportation are likely to be constrained in the inner city where has good transit services and walkable environment, and such locations would bring about more ridership and pedestrian travel (Cao et al., 2009). In this circumstance, the mode choice precedes residential decisions. Similarly, households that value urban amenities are likely to select neighborhoods with parks, retail, or restaurant, and may have frequent leisure activities subsequently. Overall, accessibility tends to meet household or personal demand rather than modify their behavior.

Nevertheless, a few researchers argue that the impacts of residential endogeneity are limited (Ewing & Cervero, 2010). In reality, selecting a residence is not flexible for many households. Due to different kinds of constraints, many people have remained at current places for a long time and are not able to move into neighborhoods with desired features (Chatman, 2009, p.1087). For example, researchers found that neighborhood amenities substantially drive up housing prices (Li et al., 2016; Song & Knaap, 2004), which is likely to deter households with lower income from moving in.

Previous studies have suggested many statistical techniques to overcome the endogeneity problem in regression. Much research conducts longitudinal analysis to mitigate the impacts of residential self-selection (Hu & Giuliano, 2017; Weinberg et al., 2004) or use two-stage models with an instrumental variable (Boarnet & Wang, 2019; Jin & Paulsen, 2018). A good instrument needs to meet a number of requirements, making it highly challenging to find an appropriate one (Matas et al., 2010). It is also notable that two-step models are unstable if dependent variables are discrete (Wooldridge, 2002, pp.472-478). Besides that, some researchers perform analysis on a sub-group whose residences are exogenously given, such as youth (Ihlanfeldt & Sjoquist, 1990). This method is valid but has difficulties generalizing findings to the general population because the filtering criteria are pertinent to socioeconomic characteristics. Several studies improve this strategy by selecting the sub-sample based on the length of staying at current residence, e.g., 10 years, assuming the residential locations of long-term dwellers are exogenous (Hu, 2019; Korsu & Wenglenski, 2010; Matas et al., 2010). The practical limitation of this refined strategy is that the length of residence is not a common variable in U.S. travel surveys.

Many recent studies apply the structural equations model (SEM) to explore the effects of accessibility while disentangling complicated interrelationships among endogenous variables

(Aditjandra et al., 2012; Ding et al., 2017; Gao et al., 2008). SEM is built based on theoretical foundations, which incorporates a set of basic statistical methods, including confirmatory factor analysis and path analysis. It is particularly helpful for understanding relations among several variables that are supposed to be interrelated. Researchers typically employ this statistical technique to conduct analysis at the aggregated level (Gao et al., 2008) because it has difficulties processing discrete variables, such as individuals' mode choice and employment status (Mokhtarian & Cao, 2008). However, much software supports categorical variables in SEM nowadays, and hence a growing number of studies have used individual-level data in SEM (Liu et al., 2017; Wang & Chai, 2009).

Examining the effects of accessibility on travel behavior is of great complexity, which favors the application of advanced modeling techniques. As reviewed earlier, many factors can influence travel behavior. Meanwhile, these factors tend to be associated with each other, generating multiple equations between them. As an advanced statistical technique, SEM is able to solve a set of regressions simultaneously and can help researchers to understand to what extent the hypothesized relation is straightforward or through the mediation of other variables (Kline, 2010). On the whole, the capabilities of SEM would facilitate a thorough understanding of the accessibility effects on non-work travel. Therefore, my dissertation adopts the SEM approach.

Chapter 3. Study Area, Data, and Methodology

3.1. Study Area

This dissertation focuses on the travel behavior of residents in Milwaukee County because the county has a notable portion of the disadvantaged population. Their accessibility is measured at the regional level since Milwaukee County residents still need to travel to some non-work destinations outside of the county.

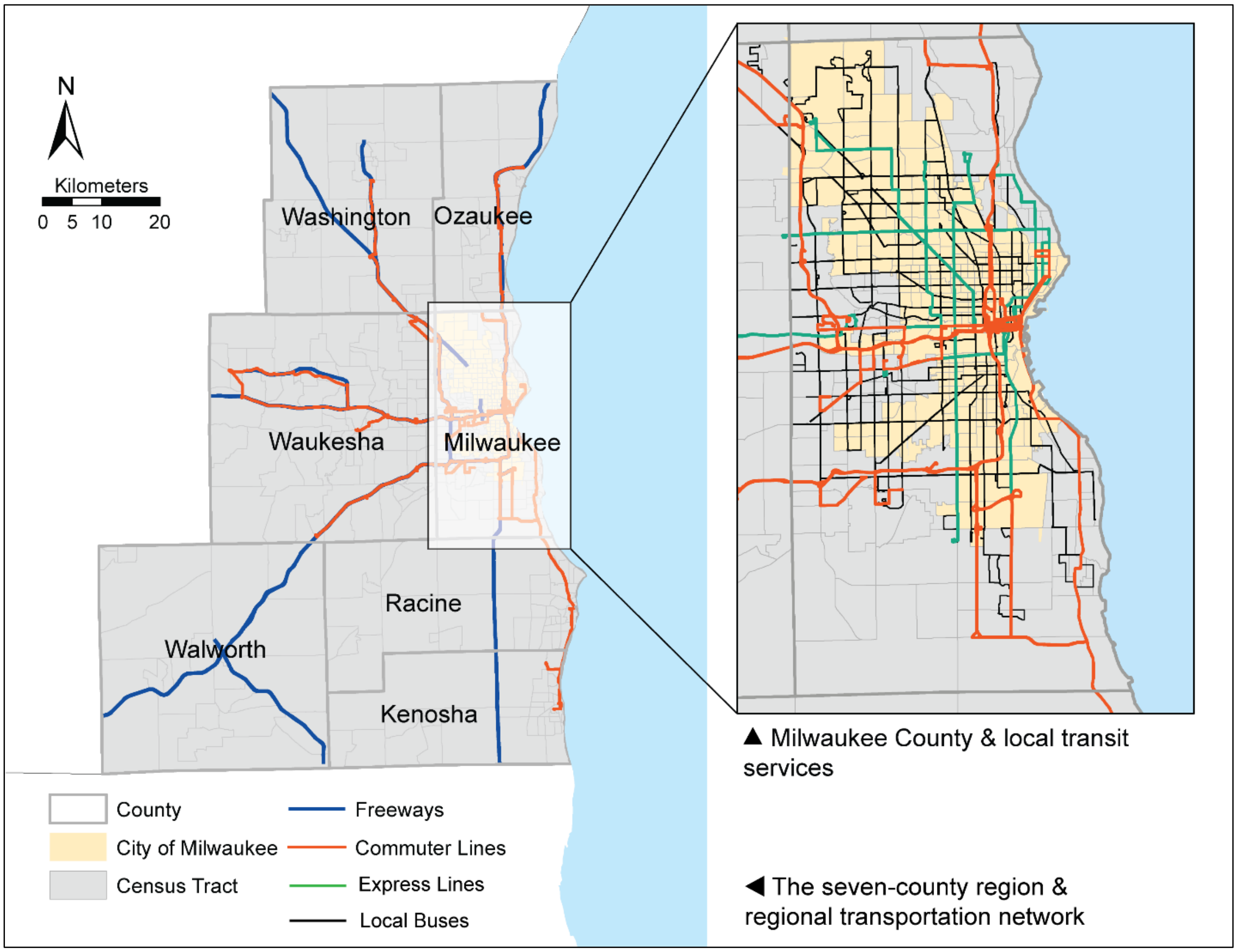
3.1.1. The Seven-County Southeastern Wisconsin Region

The seven-county region in Southeast Wisconsin includes the counties of Milwaukee, Racine, Kenosha, Waukesha, Walworth, Washington, and Ozaukee. The geographic unit of analysis is the census tract, and there are 534 census tracts in the region. The land area of this region is 6,959 square kilometers, and the total population was 2,042,648 in 2018 (U.S. Census, 2018). The central county is Milwaukee County, and the major city of the region is the city of Milwaukee. Figure 1 shows the geography and transportation network of the study area.

The region has convenient transportation for automobile travel throughout the region but limited transit services mainly in Milwaukee County. Its highway network is extensive, linking the seven counties. Regional transit services are only available for commuter routes operated along highways on weekdays, primarily helping suburban workers reach job opportunities in Milwaukee County during morning and afternoon peak hours. Cross-county transit riders have difficulties in traveling throughout the region on weekends or during off-peak hours on weekdays.

This dissertation measures regional accessibility, i.e., accessibility to various non-work opportunities located within the seven counties because some non-work destinations serve the entire region. This dissertation uses employment data reported at four essential non-work destinations to illustrate the distribution of non-work opportunities in the entire region. Employment size is expected to be proportional to goods/service opportunities.

Figure 1. Study Area



3.1.2. Milwaukee County

This dissertation focuses on residents living in Milwaukee County, but a notable portion of their travel is conducted in the whole seven-county region. Milwaukee County deserves special research attention because the disparities in income levels and population composition between Milwaukee County and the seven-county region are pronounced. Specifically, Milwaukee County concentrates a higher proportion of people who are potentially disadvantaged groups, such as minorities and unemployed populations, and households in Milwaukee County tend to earn less and are less likely to own vehicles (Table 1). The relatively inferior socioeconomic status may result in travel difficulties, which would require policy interventions. Besides, Milwaukee County residents are likely to use multiple transportation modes because the county provides a variety of options. This will facilitate a comprehensive understanding of non-work travel behavior.

Table 1. An Overview of the Seven-County Region and Milwaukee County

	The seven-county region	Milwaukee County
Population (2018)	2,042,648	954,209
Median Household income (2018 USD)*	$61,365	$48,742
% Racial/Ethnic minorities (2018)	31.1%	48.3%
% Households without a vehicle (2018)	9.0%	13.6%
Unemployment rate (2018)	3.2%	4.0%

Source: U.S. Census, 2013-2018 5-year ACS
* Southeastern Wisconsin Regional Planning Commission (SEWRPC), 2020, Southeast Wisconsin Comprehensive Economic Development Strategy, p.28

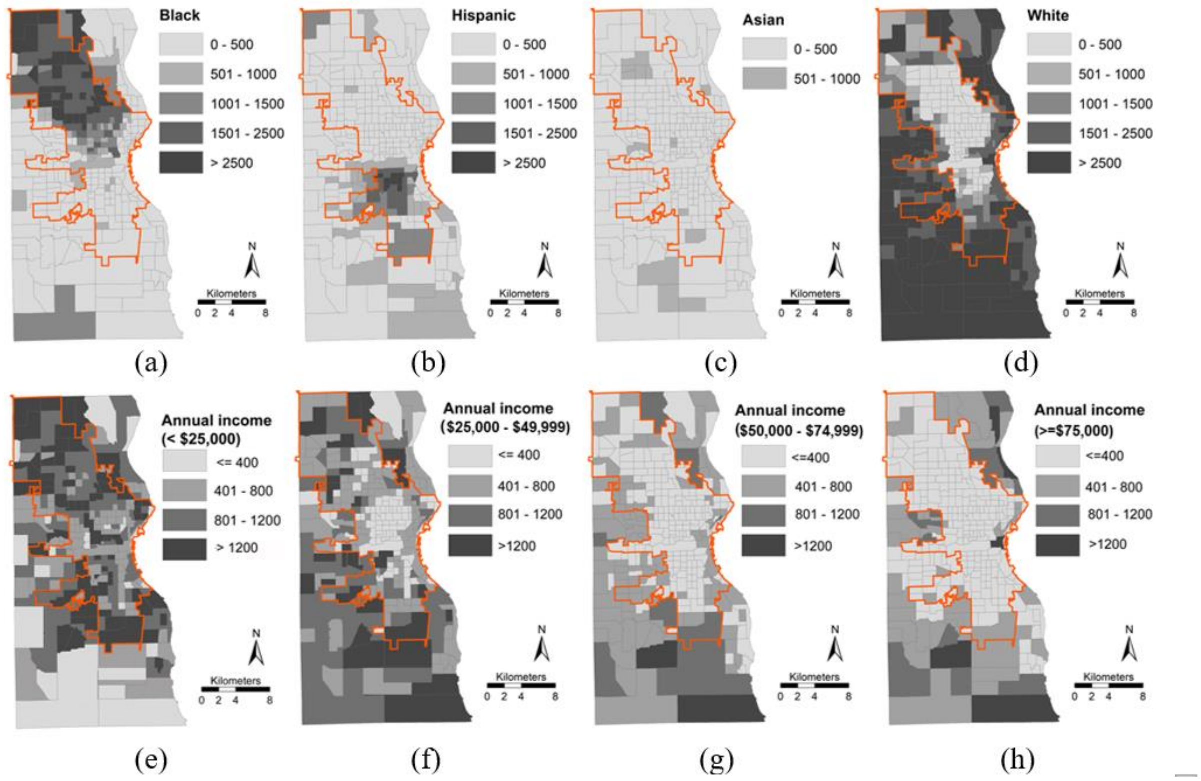
Milwaukee County contains 315 census tracts. It had a population of 954,209 in 2018 (U.S. Census, 2018), accounting for 46.7% of the region's total population. The population density in Milwaukee County is the highest in the seven-county region, ranging from 2000 to 4000 people per square kilometer. In the central parts of Milwaukee County, the population density is above 4000 people per square kilometer.

Milwaukee County is classified as an urban county. The Housing and Community Development Act (HCDA) of 1974 states that an urban county should " has a population of 200,000 or more, not including metropolitan cities located therein" (Department of Housing and Urban Development, 2019). Excluding the population of the city of Milwaukee, Milwaukee County had a population of 357,323 in 2018, which meets the above criteria.

Besides, Milwaukee County is the hub of transportation services. The local service operator, Milwaukee County Transit System (MCTS), is the largest transit agency in Wisconsin. It offers local bus lines and express lines. In addition, there are some new mobility options in the city of Milwaukee, such as streetcars, shared bikes, and scooters. The city of Milwaukee is also a pedestrian-friendly city. Places such as downtown and the lakefront have different types of amenities within walking distances.

Residential distribution patterns are associated with population groups' unequal access to opportunities, and disparities in residential locations are particularly distinct among population groups of different racial/ethnic identities and incomes. Figure 2 presents the population distribution by race/ethnicity and income levels. Black residents are highly concentrated on the northwest side of Milwaukee (Figure 2a) while Hispanics are mainly clustered in the Milwaukee South (Figure 2b). Compared with the concentrations of Blacks, the spatial range of the Hispanic enclave is much smaller. Asians are not severely constrained in certain parts of the region, and they are dispersed in both downtown and the outskirts of Milwaukee County (Figure 2c). In contrast, whites tend to live in suburbs (Figure 2d). This dissertation classifies the population into four categories based on individual income over the past 12 months. Lower income groups reside in and near the city of Milwaukee (Figures 2e and 2f), whereas higher income groups tend to be dispersed in suburbs (Figures 2g and 2h).

Figure 2. Population Distribution in Milwaukee County



3.2. Data

This dissertation relies on secondary data sources. Figure 3 shows data sources and purposes.

First, this dissertation acquired the block-level employment data from the Workplace Area Characteristics (WAC) dataset from the 2017 Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES). Employment data reported at workplaces can reflect both the size and location of destinations. This dissertation selected four NACIS sectors that offer essential services and goods (sector 62 Healthcare and Social Assistance; sector 71 Arts, Entertainment, and Recreation; sector 72 Accommodation and Food Services; sector 44-45 Retail Trade). The number of jobs in these four sectors are used as the proxy for the number of non-work opportunities. The block-level data were then aggregated by census tract.

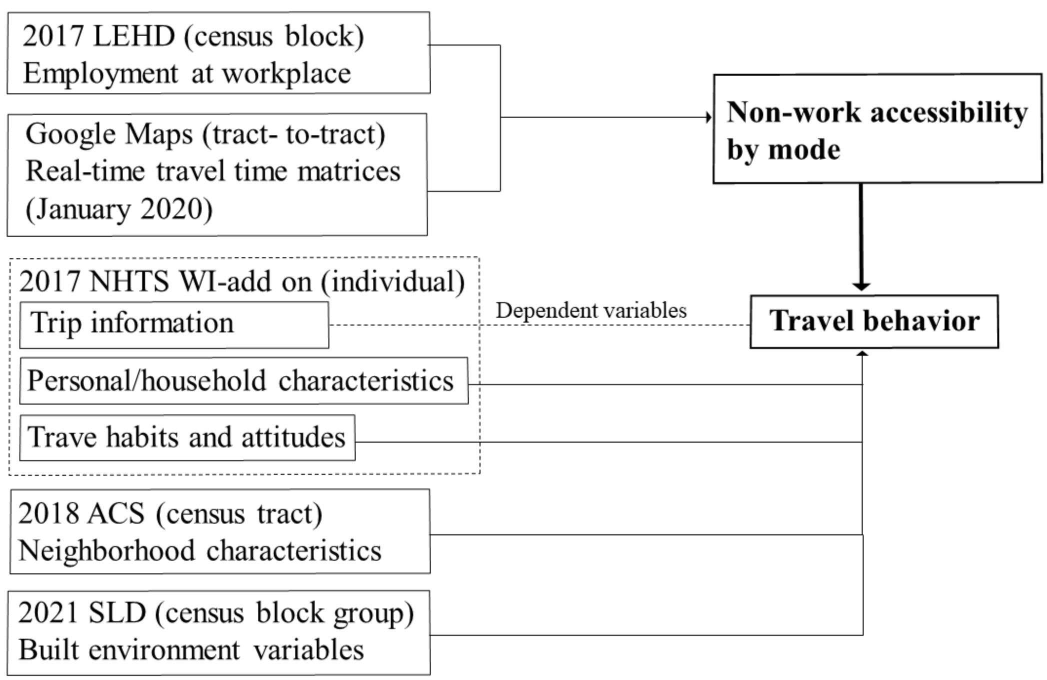
Second, this dissertation obtained centroid-to-centroid interzonal travel time from Google Maps using an API key. Assuming non-work trips are made during off-peak hours, the departure time is set as 11 a.m. on a Tuesday to minimize the impacts of commutes on traffic. Travel times by three transportation means (automobile, transit, and walking) are estimated, respectively. There are no official documents that describe the algorithm used by Google Maps to generate travel times. But an interview with a former engineer of Google mentioned that the prediction of travel time by automobile is determined by a variety of factors, such as real-time traffics, speed limits, and the actual driving time of previous users (Szoldra, 2013). Travel time by transit, which includes in-vehicle, waiting, and transfer time, is calculated according to the best route chosen by Google Maps. Based on feedback from Google Maps users, the estimated walking times consider elevations, assume an average walking speed of 2.8mph, and are calculated primarily based on routes along sidewalks (both paved and unpaved).

Google Maps cannot provide intrazonal travel time within census tracts because the centroids of census tracts are used as both origins and destinations. This dissertation calculated intrazonal travel time by dividing travel distance—half of the square root of land area—by an average speed of 35mph, 20mph, and 2.8mph for automobile, transit, and walking, respectively. The speed limit is approximately 35 mph on city streets, and transit, such as buses, is assigned a speed of 20 mph due to frequent stops.

Third, the Wisconsin Department of Transportation (WisDOT) provided the 2017 National Household Travel Survey (NHTS) WI add-on dataset. The add-on dataset recorded travelers' demographic and socioeconomic characteristics as well as detailed trip information (e.g., trip purpose, trip mode, trip time, and the coordinates of origins and destinations) on assigned travel days. It also included the self-reported frequency of using certain transportation modes, which can reveal travelers' travel habits and preferences. This dissertation focuses on trips with four types of travel purposes: shopping, seeking healthcare, visiting recreational sites, and getting meals.

Besides that, the 2021 Smart Location Database (SLD) from the Environmental Protection Agency (EPA) provides the built environment data. 2018 ACS 5-year estimate from U.S. Census gives demographic information of census tracts.

Figure 3. Data Sources and Purposes



3.3. Methodology

3.3.1. Measure Accessibility

This dissertation applies a non-competitive gravity-based method to measure accessibility to four types of non-work destinations by three transportation modes. The gravity-based method discounts opportunities by an impedance function (e.g., exponential function) of travel time, and then adds up all weighted opportunities. Equations (1) and (2) are used to calculate the gravity-based accessibility to non-work opportunities, and Figure 4a visually explains the calculation process.

$$A_{i,m} = \sum_j O_j f(C_{ij,m}) \quad (1)$$

$$f(C_{ij,m}) = e^{(-b_m C_{ij,m})} \quad (2)$$

Where

$A_{i,m}$ = accessibility to non-work opportunities by mode m in census tract i;

O_j = the number jobs at non-work destinations in census tract j;

$C_{ij,m}$ = centroid-to-centroid travel time by mode m from census tract i to j;

m = transportation modes (m =1: automobile, m =2: transit, and m =3: walking);

b_m = impedance factor of mode m (b=0.01945 when m =1; b=0.00648 when m =2; b=0.02438 when m =3). It is estimated by the log-linear least square model, using the actual travel time of all non-work trips from the NHTS WI-add on as the independent variable and the natural log of the travel time frequency as the dependent variable.

To understand the disparity in accessibility, this dissertation estimates the weighted average accessibility to non-work opportunities by different modes for different sociodemographic groups:

$$Ratio_i = N_i / \sum_i N_i \quad (3)$$

$$AveAccess_m = \sum_i (A_{i,m} * Ratio_i) \quad (4)$$

Where

N_i = population of certain sociodemographic characteristics in census tract i;

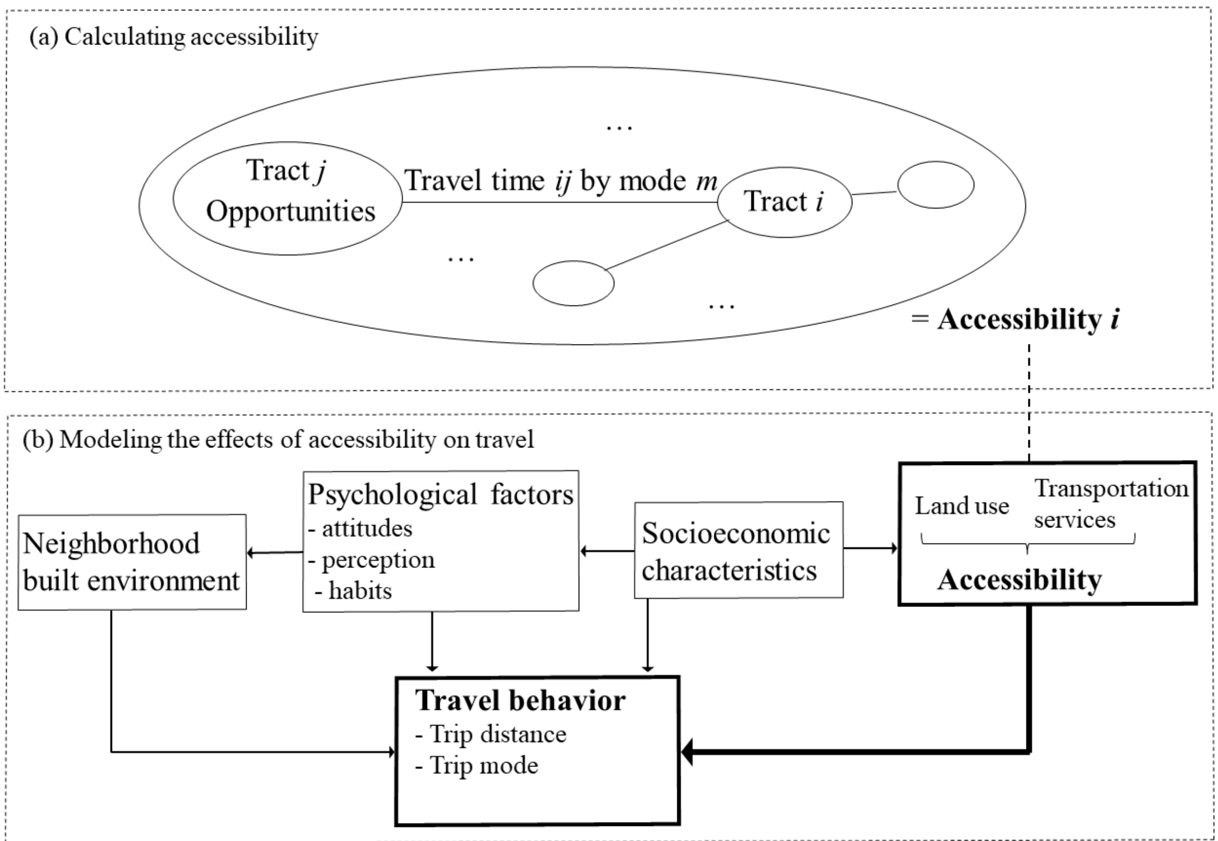
$\sum_i N_i$ = population of certain sociodemographic characteristics in all census tracts; e.g., all low-income people;

$Ratio_i$ = the percentage of the population of certain sociodemographic characteristics in census tract i ;

$AveAccess_m$= the weighted average accessibility by mode m.

All the other notations are the same as in previous equations.

Figure 4. Conceptual Framework



3.3.2. Model the Effects of Accessibility

Another focus of this dissertation is to model the effects of accessibility to non-work opportunities on travel. Figure 4b presents the conceptual framework.

The model contains four sets of independent variables, reflecting the major factors that affect travel behavior. Accessibility represents land use at the macroscale, i.e., the spatial distribution of opportunities, and transportation services. Meanwhile, neighborhood built environment, which reflects land use features at the microscale, is included. Socioeconomic characteristics and psychological factors are also influential determinants of travel behavior based on literature. Four causal links from these variables to travel behavior are established.

The model is constructed based on travel behavior theories. Travel is a derived demand; people want to reduce travel costs to maximize utility. In this way, travel costs can affect specific travel behavior, while accessibility is closely associated with travel costs. Therefore, accessibility is the key variable in the model, and the causal link from accessibility to travel is the focus of this analysis.

Some independent variables affect each other. First, the arrow from socioeconomic characteristics to accessibility indicates the process of choosing residential location. Literature has documented that socioeconomic characteristics (e.g., income) largely influence people’s residential location choice in a region and hence affect one’s accessibility. Second, at the neighborhood level, people tend to choose residences that fit their preferences on amenities and travel habits. Therefore, psychological factors, including attitudes, perceptions, and habits, can impact neighborhood built environment (e.g., density and design). Third, people with different socioeconomic status tend to have distinct habits, attitudes, and preferences. Accordingly, the causal link from socioeconomic characteristics to psychological factors is constructed.

For each type of non-work activity, two indicators of travel behavior (trip distance and trip mode) are explored. Trip distance is an important indicator because it is associated with one’s wellbeing. Long-distance travel has been claimed as a financial burden by many individuals, and excessive travel is also harmful to health (Lyons & Chatterjee, 2008). Theoretically, people want to minimize travel costs, meaning that all else being equal, closer destinations and hence shorter trips are usually preferred. High accessibility, which helps people find the desired destination nearby from abundant choices, is expected to shorten trip distance.

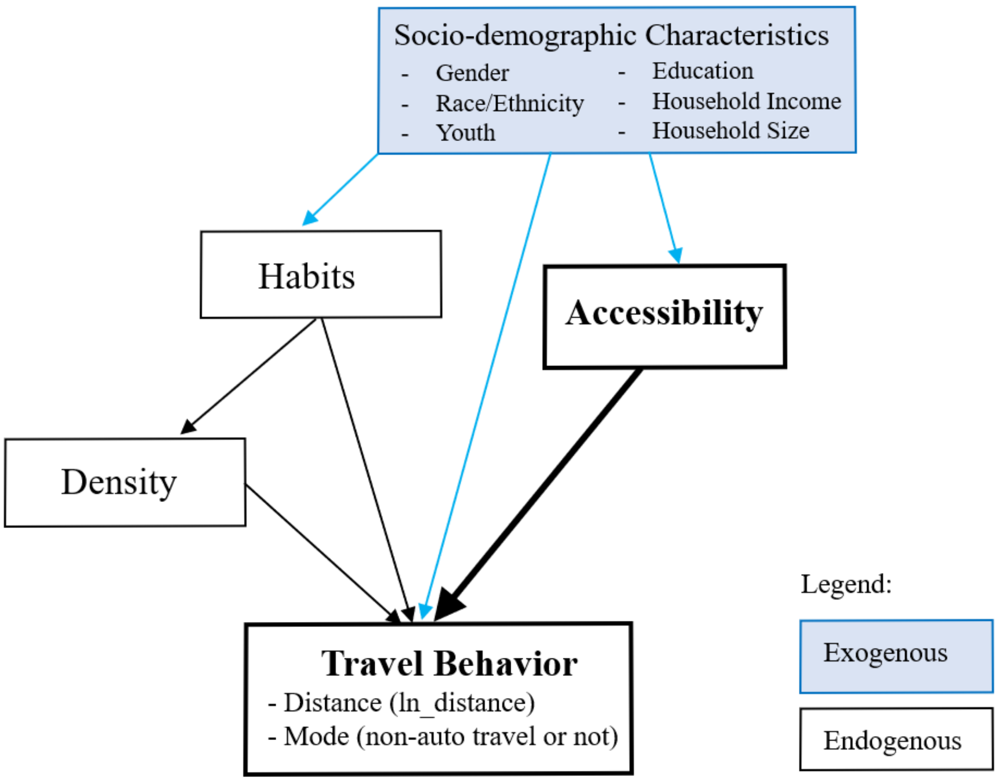
In addition, trip mode is examined. Automobile travel has detrimental effects on health (Jacobson et al., 2011) and generates environmental externalities (Button, 2010, p.166). To improve wellbeing and promote sustainability, it is of great significance to understand how people choose between automobile and alternative modes, i.e., non-automobile modes. This dissertation hypothesizes that high accessibility increases the likelihood of taking non-automobile trips. Still, travel costs play an important role in mode choice. Commonly, planning non-automobile trips is relatively time-consuming since sidewalks, bicycle trails, and transit services are not as pervasive as motorways, which is likely to discourage the use of non-automobile modes. Specifically, it is necessary to identify bicycle lanes or trails (Schneider, 2013). Similarly, people need to decide routes for walking trips and find the best transit routes based on departure time. Nevertheless, trip planning time, i.e., travel costs, can be shortened if desired destinations are nearby or transportation services and infrastructure (e.g., sidewalks, bike lanes) are convenient. In this way, higher accessibility is expected to reduce the travel costs of using non-automobile modes, increasing the competitiveness of non-automobile modes relative to automobiles and thus the likelihood of taking non-automobile trips .

However, trip distance and trip mode affect each other. Trip distance influences the choice of trip mode, and based on the mobility of different transportation modes, trip mode also has impacts on trip distance. Typically, automobiles generate long-distance trips, whereas non-automobile modes result in short-distance travel. The conceptual model does not contain this bidirectional relationship because this dissertation primarily focuses on the causal relationship between accessibility to non-work opportunities and each travel indicator.

Given the complexity of established causal relationships, this dissertation adopts structural equation modeling (SEM) to examine the effects of accessibility on travel behavior.

Figure 5 shows the model diagram, which is developed based on the above theoretical framework and will be tested in the statistical analysis software R. In total, eight models (four types of non-work activities × two travel behavior indicators) are tested.

Figure 5. Model Diagram



There are two types of variables in the model diagram: endogenous variables and exogenous variables. The arrows indicate the direction of hypothesized relationships. Endogenous variables depend on other variables in the model and often have both incoming and outcoming arrows, whereas exogenous variables are independent in the model. Based on literature and data availability, the model diagram contains four endogenous variables and six exogenous variables.

Table 2 describes these variables in detail. Accessibility in the model refers to the ratio of accessibility by walking to accessibility by automobile of the trip's origin census tract. This dissertation uses the ratio of accessibility by two different travel modes because the model can only include one accessibility variable to avoid multicollinearity. Besides, the ratio can capture the disparity between walking-based and automobile-based accessibility. Previous studies have applied this approach and yielded unbiased results (Kawabata, 2003).

The variable Habits is binary in the model and represents having travel habit of using non-automobile modes or not. This dissertation uses the self-reported frequency of using non-automobile modes in the NHTS dataset as the proxy for travel habits. This dissertation tried all the "D" variables (Density, Diversity, and Design). Density was selected to control for built environment characteristics because it significantly improves the model fit.

Table 2. Variable Descriptions

Type	Variable	Source	Description
Endogenous	Accessibility	This dissertation	The ratio of accessibility by walking to accessibility by automobile.
Endogenous	Habits	NHTS	Binary; original answers like a few times a week or a few times a month mean having habits for using non-auto, which are coded as '1', answers including a few times a year or never indicate not having habits for using non-auto and thus are coded as '0'.
Endogenous	Density	SLD	Continuous; gross residential density (Housing unit/acre)
Endogenous	Travel distance	NHTS	Continuous; unit: miles; derived from travel route; log transformed
Endogenous	Travel mode	NHTS	Binary (non-automobile travel or not) '1' for non-auto modes (walking, bicycling, transit) and '0' for automobile (car, van, etc.)
Exogenous	Gender	NHTS	Binary; '1' for female and '0' for male.
Exogenous	Race/Ethnicity	NHTS	Binary: '1' for racial/ethnic minorities and '0' for whites
Exogenous	Youth	NHTS	Binary: '1' for 16-24 and '0' for adult 25 and above
Exogenous	Education	NHTS	Binary: '1' for high education (bachelor and above) and '0' for low education (other levels)
Exogenous	Household income	NHTS	Continuous
Exogenous	Household size	NHTS	Continuous

Chapter 4. Accessibility to Non-work Destinations

This chapter aims to answer the first research question: are there disparities in accessibility to non-work opportunities across different sociodemographic groups? Section 4.1 describes the distribution of the four types of opportunities. Section 4.2 visually presents the results of the accessibility to opportunities by the three transportation modes. Section 4.3 examines accessibility disparities.

4.1. Descriptive Analysis

Assuming goods/service supply is proportional to the employment size of the specific goods/service, this dissertation uses employment reported at workplaces as the proxy for non-work opportunities of healthcare, retail, recreation, and food services. The following table and figures describe the distribution of the four types of non-work opportunities in the region. Table 3 gives the employment in healthcare, retail, recreation, and food services by county. Milwaukee County has the greatest number of these jobs, followed by Waukesha County. These two counties together provide nearly or more than 70% of jobs in all four sectors. Within Milwaukee County, the percentage of jobs in the city of Milwaukee is higher than the rest of Milwaukee County.

However, the difference in healthcare and retail jobs between the city and suburban Milwaukee is much smaller than those in the other two sectors of recreation and food. Healthcare centers and retail stores in the study area could be more heavily affected by the relatively lower land rent in suburban locations due to their needs for large space, while consistent with literature, restaurants and recreational facilities like museums and art galleries tend to locate in the city center to enjoy agglomeration economy.

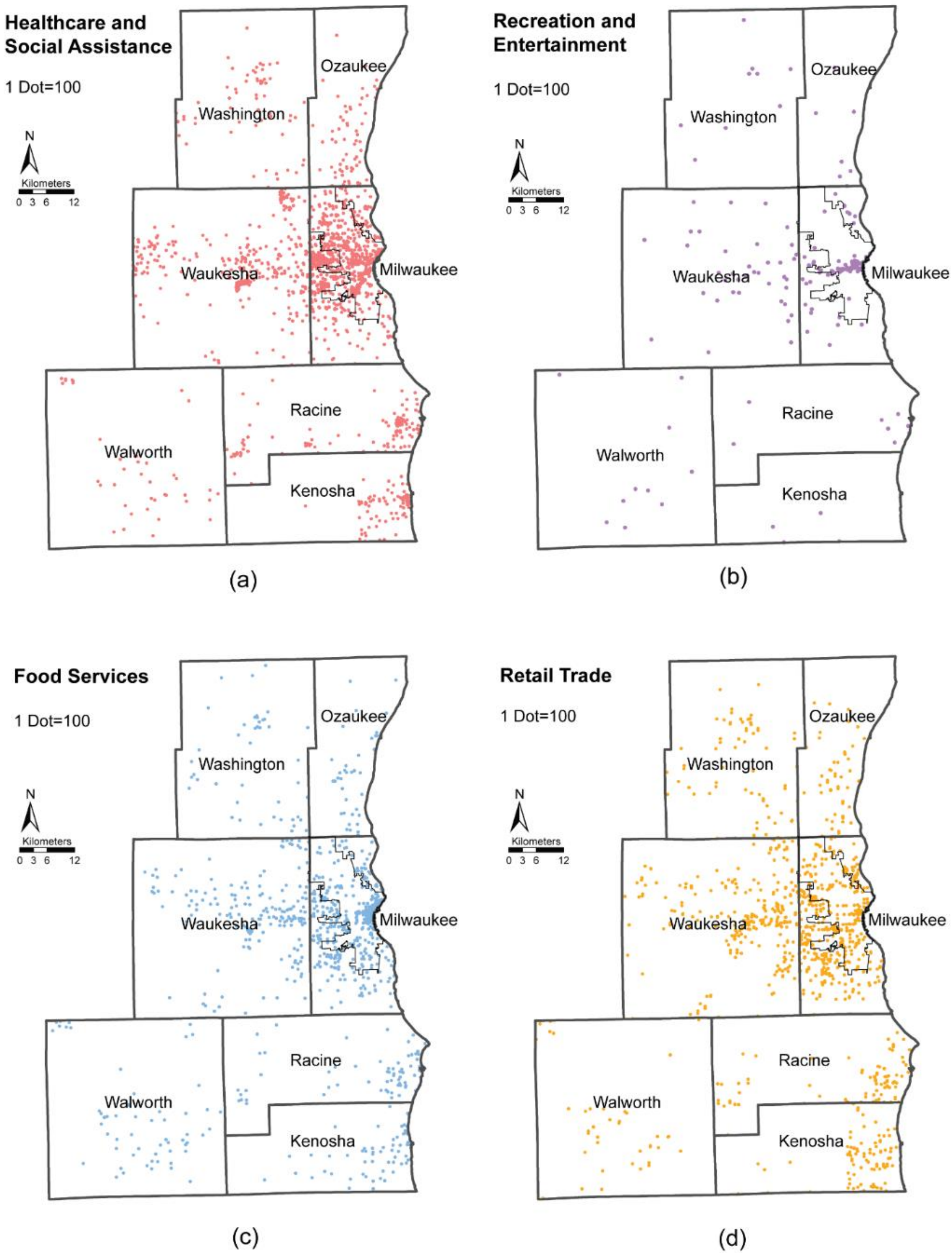
Table 3. Employment in Four Sectors by County

County name	Healthcare		Retail		Recreation		Food Services	
	#	%	#	%	#	%	#	%
Milwaukee County	96386	59.8	46888	43.8	10528	54.7	41852	49.2
The city of Milwaukee	58825	36.5	29294	27.4	8313	43.2	29240	34.4
Other	37561	23.3	17594	16.4	2215	11.5	12612	14.8
Racine County	11060	6.9	8905	8.3	1040	5.4	6417	7.5
Kenosha County	8823	5.5	8796	8.2	719	3.7	6060	7.1
Waukesha County	28882	17.9	26368	24.6	3947	20.5	17059	20.0
Washington County	5950	3.7	7003	6.5	996	5.2	4477	5.3
Walworth County	3994	2.5	4317	4.0	1177	6.1	5589	6.6
Ozaukee County	6190	3.8	4814	4.5	828	4.3	3663	4.3
Total	161285	100	107091	100	19235	100	85117	100

Source: 2017 Longitudinal Employer-Household Dynamics (LEHD)

Figure 6 shows the spatial distribution of these employment, i.e., non-work opportunities. Similar to the information provided in table 3, all four types of jobs are centralized in Milwaukee County and some parts of Waukesha County. Opportunities in healthcare and social assistance are dense in the middle part of Milwaukee County and the center of Waukesha County (Figure 6a). Opportunities in recreation show a high concentration in the central part of the city of Milwaukee (Figure 6b). The rest of Milwaukee County has limited recreational opportunities. Food services are clustered by the lakefront in the city of Milwaukee, and in general, the south side of the city of Milwaukee tends to have more opportunities for meals than the north side (Figure 6c). The distribution of retail services within Milwaukee County is relatively even with minor differences between the city and suburbs, and the center of Waukesha County also has retail clusters (Figure 6d). In the other five counties, opportunities in all these four sectors are scarce and dispersed.

Figure 6. Spatial Distribution of Employment/Non-work Opportunities



4.2. The Spatial Patterns of Non-work Accessibility

This section visually presents accessibility to non-work opportunities, calculated based on Equations (1) and (2) specified in Chapter 3. Walking-based accessibility is firstly presented, followed by automobile- and transit-based accessibility.

Figure 7 shows the spatial patterns of walking-based accessibility. The maps visualize accessibility in graduated color with multiple classes but do not use the same legend because there are huge differences in accessibility ranges between the four types of opportunities. For example, the first class of accessibility to healthcare is lower than 5000, which covers three classes in accessibility to recreation.

Nevertheless, the spatial patterns are similar for all the four types of non-work accessibility: accessibility is highest in the geographic center of Milwaukee County and decreases as the distance from the center increases. Additionally, places of high non-work accessibility appear limited. In other words, the majority of the region has low accessibility to the four types of non-work destinations by walking.

Minor differences are also observed. Places of high accessibility to healthcare are located at the geographic center of Milwaukee County, while places of high accessibility to food services and recreational facilities tend to locate closer to Lake Michigan lakefront. Besides, there are multiple peaks of accessibility to retail stores, and the largest peak is located in the western part of Milwaukee County, close to Waukesha County boundary.

Such spatial patterns are expected. Healthcare services tend to co-locate with industries like information technology and education in the center of the county. Software companies located in downtown Milwaukee can provide technical support for medical treatment facilities and patient management system. Besides, healthcare services have active connection with education institutes, such as Medical College of Wisconsin, located at the east side of Milwaukee

County, to conduct clinical research and train medical professionals. For these reasons, places in the central areas have high accessibility to healthcare. Many recreational facilities locate in the center of the city because they need to serve the whole region and are likely to be the landmarks, such as Milwaukee Art Museum and Fiserv Forum (the home of NBA Milwaukee Bucks). Service industry, particularly food services such as restaurants and cafes, tends to follow recreational facilities in order to share customers. In the seven-county region, the lakefront in downtown Milwaukee has a cluster of museums and restaurants as well as walkable environment, which can explain the high walking-based accessibility to recreational destinations and food services of these areas. Retail trade, which refers to stores selling home furniture, appliance, electronics, clothing, and grocery, may need larger space and tends to locate in and near suburbs following population suburbanization. Thus, accessibility to retail opportunities is highest in places slightly away from the city center.

Figure 8 shows automobile-based accessibility to the four types of non-work destinations. The spatial patterns are similar. Accessibility peaks in the geographic center of Milwaukee County and declines gradually as distance from the center increases. Apparently, the spatial ranges of high automobile-based accessibility are more extensive compared to that of walking-based accessibility. The reason can be the differences in mobility between automobile and walking. Traveling by automobile can get to more distant places and thus reach more potential destinations than walking within the same time, smoothing out disparities caused by uneven spatial concentration of opportunities.

Figure 9 presents transit-based accessibility. The spatial patterns of transit-based accessibility are highly affected by the transit network. Transit services are relatively abundant in Milwaukee County. Cross-county transit generally serves to connect Milwaukee County with other parts of the region, particularly the urbanized parts of Waukesha County. Accordingly, accessibility to all the four types of destination is highest in downtown Milwaukee, and places located between Milwaukee and Waukesha counties also have high accessibility.

Figure 7. Non-work Accessibility by Walking

Figure 8. Non-work Accessibility by Automobile

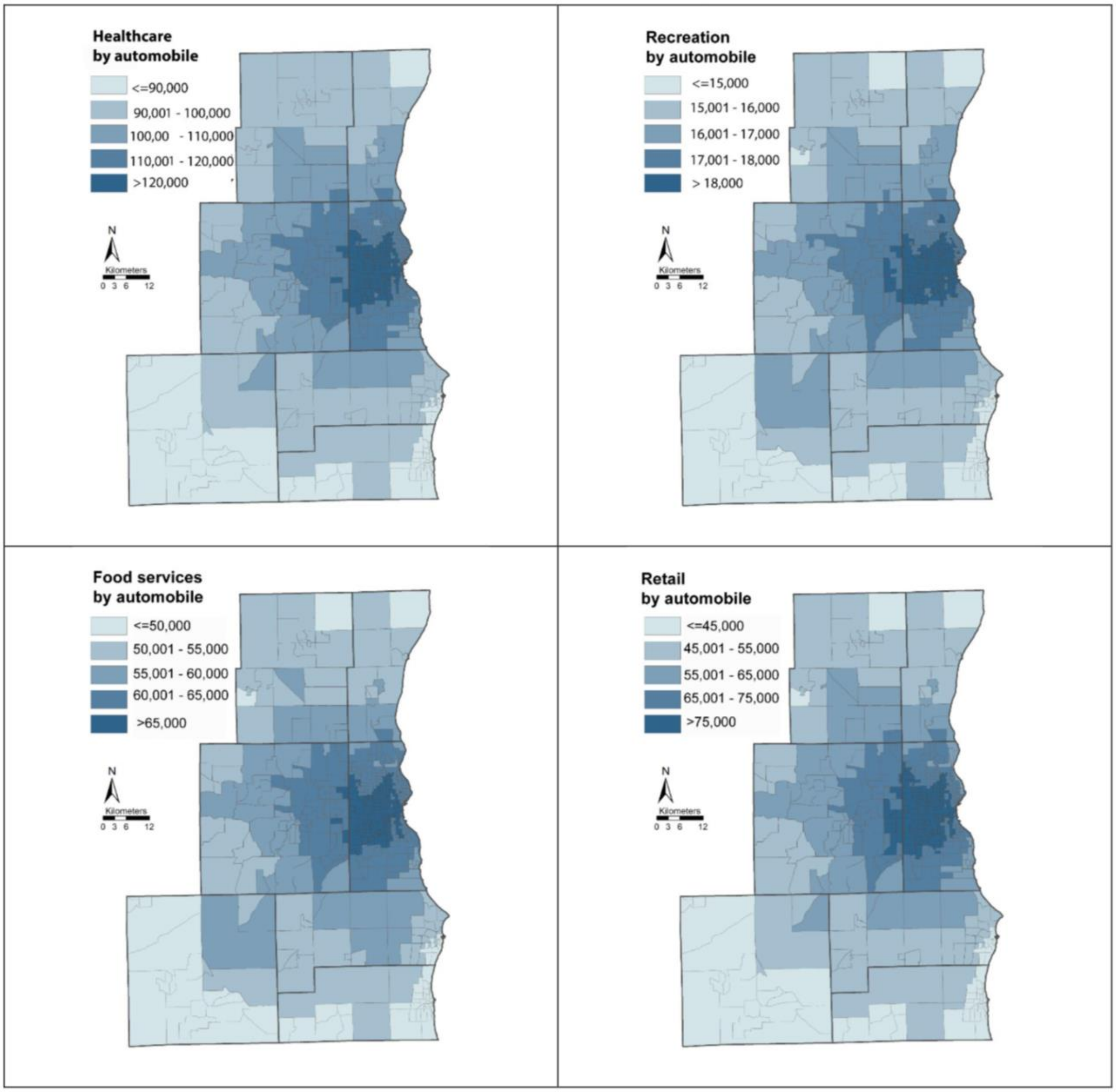
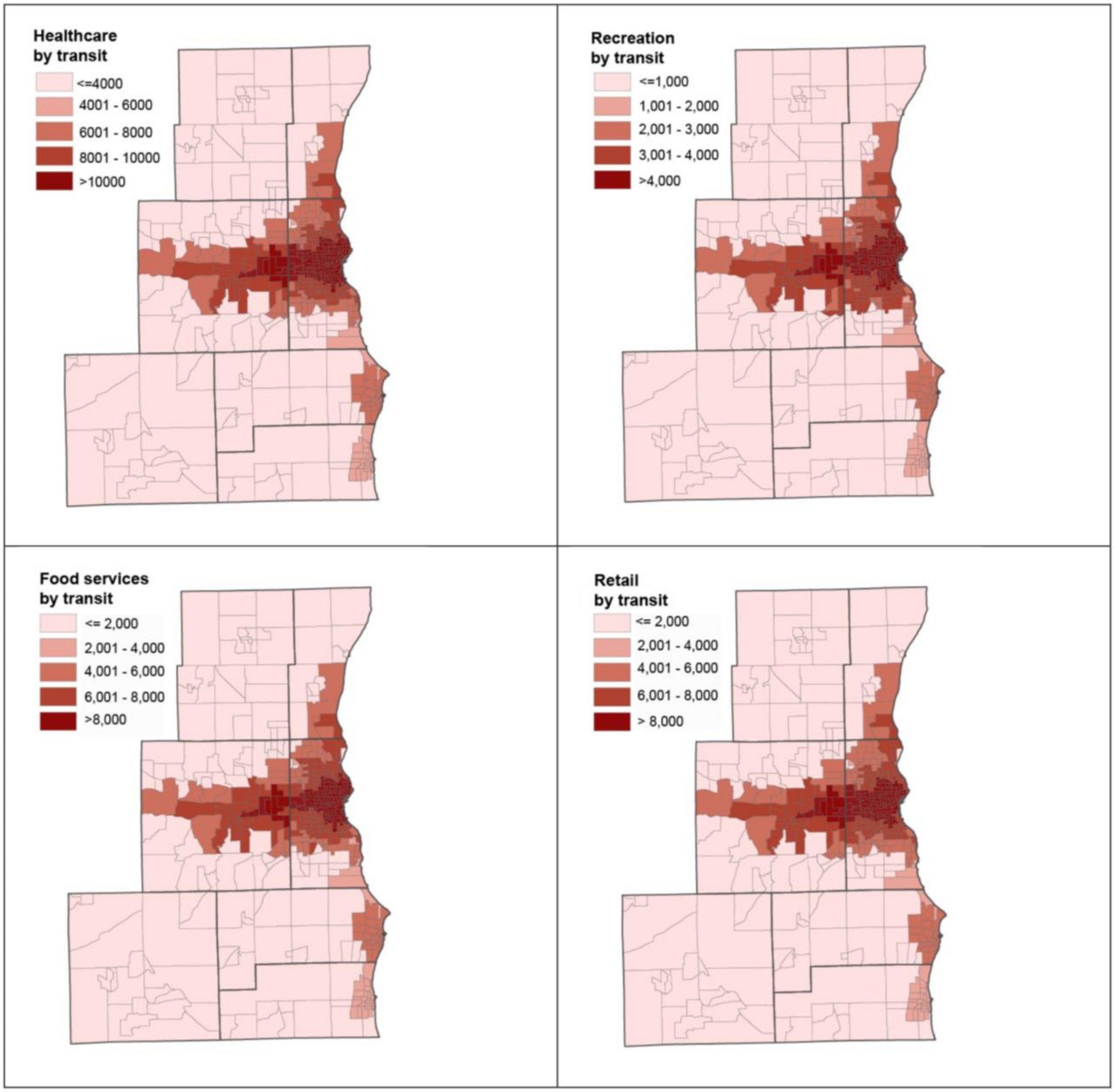


Figure 9. Non-work Accessibility by Transit



In general, two findings can be concluded. First, differences are observed among accessibility to healthcare, recreation, food services, and retail by the same travel mode, due to the location patterns of these opportunities. Second, non-work accessibility by the three transportation modes exhibits different geographic patterns. Walking-based and automobile-based accessibility are both highest in the central parts of Milwaukee County and declines away from the center, but the spatial ranges of places of high automobile-based accessibility tend to be larger. Transit-based accessibility is highest in downtown Milwaukee and decreases along transit lines towards the west, south, and north sides.

4.3. Disparities in Accessibility

This dissertation aims to examine accessibility disparities across different sociodemographic groups. As described in the study area section, this dissertation measures accessibility for the whole region but conducts analysis with special attention to Milwaukee County because the disparities in income levels and population composition between Milwaukee County and the seven-county region are pronounced. This section investigates accessibility disparities across different racial/ethnic groups and income groups in Milwaukee County. First, it compares weighted average accessibility to obtain a general understanding of disparities. Second, it overlays maps to examine the spatial gaps between accessibility and population distributions.

4.3.1. Accessibility by Race/Ethnicity

Table 4 gives the weighted average accessibility for population groups of different races/ethnicities. Disparities exist and are particularly large between whites and Blacks. Specifically, whites have the lowest accessibility to all the four types of non-work destinations by automobile, transit, or walking, whereas Blacks have the highest. Hispanics and Asians lie in the middle, but Hispanics have slightly higher transit- and walking-based accessibility to all non-work destinations than Asians, while Asians show relative advantages in automobile-based accessibility.

Table 4. Weighted Average Accessibility by Race/Ethnicity

Race/ Ethnicity	Population	Retail			Recreation			Food services			Healthcare		
		Auto	Transit	Walking	Auto	Transit	Walking	Auto	Transit	Walking	Auto	Transit	Walking
White	568948	56328	22256	2062	16152	4702	1278	59910	18992	4510	108921	37991	7151
Black	250704	**62882**	**41256**	**3625**	**16816**	**8834**	**2674**	**64007**	**35304**	**8719**	**118877**	**71555**	**15372**
Hispanic	143779	60109	35895	3398	16598	7665	2487	62482	30818	7742	114893	61796	13270
Asian	44289	62062	33139	3169	16645	7101	2092	63321	28281	7044	116737	57175	11870

Notes: The highest values for each accessibility measure (e.g., auto-based access to retail) are shown in bold.

As expected, racial/ethnic minorities generally have better accessibility than whites. The reasons would be that racial/ethnic minorities are likely to concentrate in neighborhoods in and near downtown areas, which have concentrations of non-work opportunities and transportation services. In particular, Blacks tend to experience severe residential segregation that constrains them in the city. By contrast, whites tend to be dispersed and are likely to live in places far away from downtown and with sparse non-work opportunities. Such patterns have been observed in the study area. Overall, the situation appears lenient since racial/ethnic minorities have higher accessibility, but the root cause of the patterns is severe racial segregation. Additionally, racial/ethnic groups have different levels of access to automobiles and white residents are more likely to take advantage of the high accessibility by automobile.

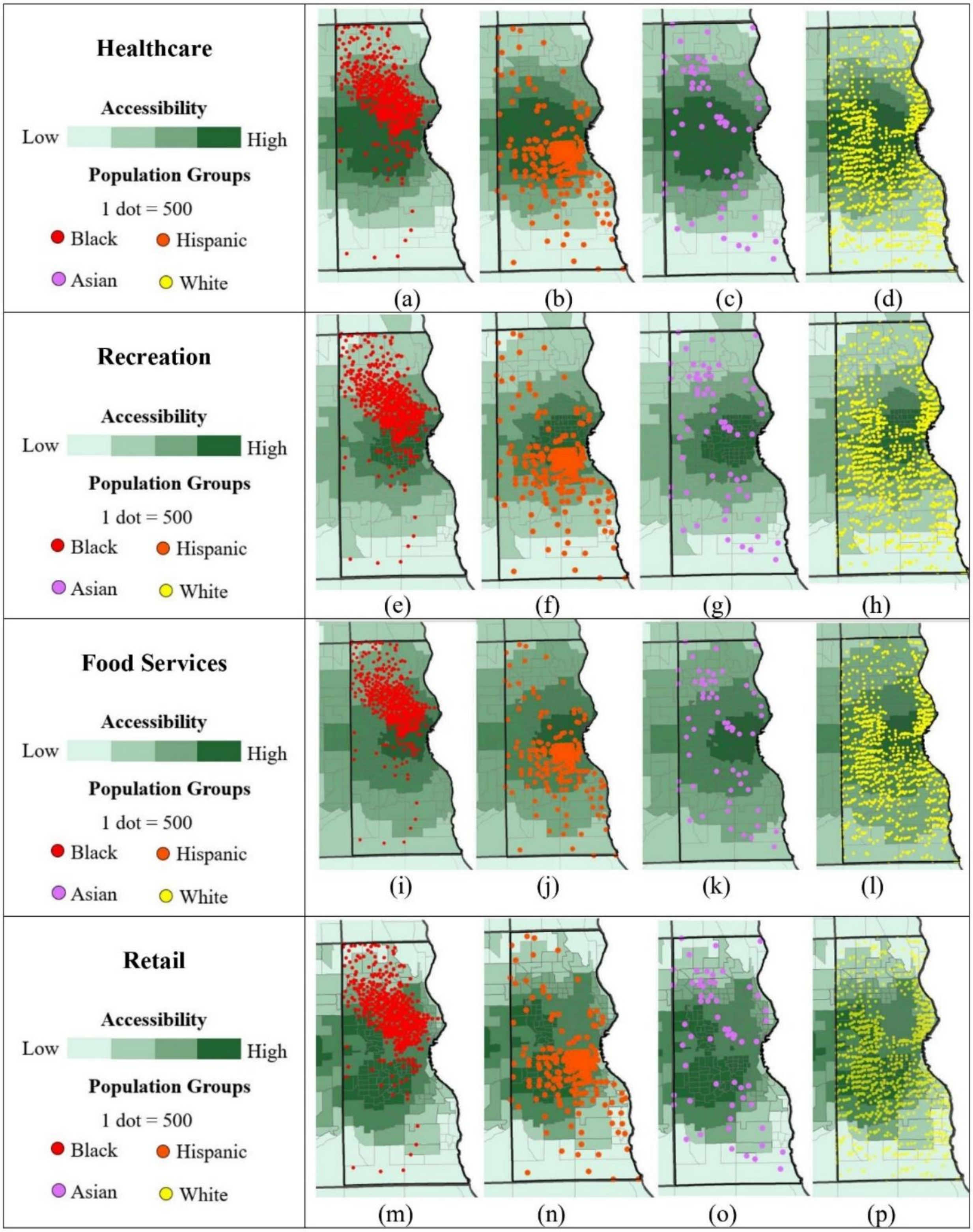
Figure 10 shows the overlays of walking-based accessibility and the residential locations of different racial/ethnic groups. It is noteworthy that Black residents living near the county center have high walking-based accessibility, while others, particularly those concentrated on the far north side, have relatively lower walking-based accessibility (Figures 10a, e, i, and m). Blacks who concentrate in places with poor accessibility are likely to be overlooked because the Black population as a whole has the highest accessibility based on the comparisons of weighted average accessibility. This suggests that policy interventions need to focus on places of high population concentrations but low accessibility. The situation is slightly different in terms of accessibility to retail. The above-mentioned in-group differences in accessibility for Blacks still exist. But the whole Black population lives away from places of high walking-based accessibility to retail (Figure 10m), meaning that the whole Black population is likely to overcome more barriers for reaching retail stores than reaching other three types of non-work opportunities.

The distributions of racial/ethnic groups are also overlaid with automobile- and transit-based accessibility, respectively, but are not presented. The findings are generally consistent for accessibility to all four types of opportunities by the three transportation modes: Black neighborhoods located on the far north side tend to be left out and thus call for policy attention.

This dissertation does not find clear spatial gaps, i.e., places of large population but low accessibility, for Hispanics, Asians, and whites. Hispanics are concentrated but those with low accessibility are distributed dispersedly. Asians and whites are spatially dispersed. In particular, those who live in places of low accessibility are scattered on each side of Milwaukee County, rather than concentrated in certain areas.

It is noteworthy that the patterns of the overlays for Blacks and Hispanics look similar, with only a portion of the population concentrated in places of high accessibility, but Blacks as a whole have higher weighted average accessibility. I suspect that Blacks who concentrate in places of high accessibility generally have higher accessibility scores than Hispanics who live in the same places. This also suggests that the accessibility disparities within the Black population might be particularly large, which again highlights the importance of policy interventions for black neighborhoods on the far north side.

Figure 10. Overlays of Walking-based Accessibility and Population Distribution



4.3.2. Accessibility by Income Levels

This dissertation classifies people into four categories based on individual income over the past 12 months: less than $25,000, $25,000 to $49,999, $50,000 to $74,999, and $75,000 or more. Table 5 gives weighted average accessibility for the four income categories. In general, the levels of weighted average accessibility decrease as annual income increases. That is, the highest income group (>$75,000) has the lowest accessibility to all non-work destinations by all the three transportation modes, whereas the lowest income group (<$25,000) has the greatest with one minor exception--the lowest income group has the highest non-automobile-based accessibility but not automobile-based accessibility. Instead, the second-lowest group ($25,000-$49,999) has the highest automobile-based accessibility to all types of non-work opportunities.

Table 5. Weighted Average Accessibility by Annual Income

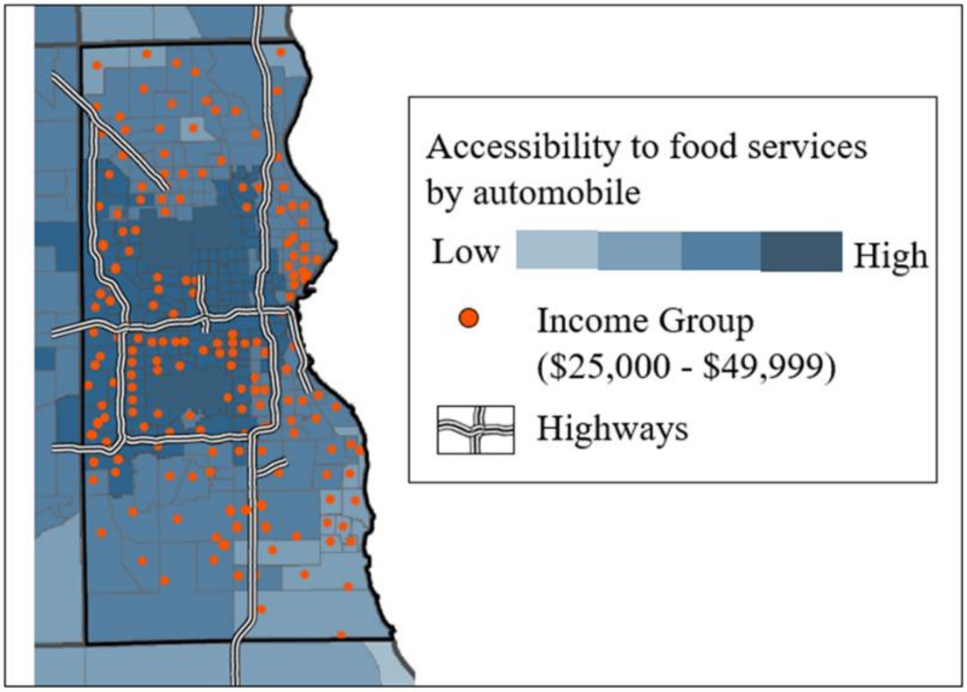
($1,000)	Population	Retail			Recreation			Food services			Healthcare		
		Auto	Transit	Walking	Auto	Transit	Walking	Auto	Transit	Walking	Auto	Transit	Walking
<25	301628	64941	**41430**	**4085**	16911	**8914**	**3061**	65244	**35458**	**9761**	120971	**71916**	**16884**
25-50	192486	**65028**	39842	4019	**16922**	8555	2855	**65283**	34100	9320	**121104**	69184	16234
50-75	99394	64756	38308	3901	16886	8206	2704	65082	32755	8999	120528	66419	15489
>75	75761	64317	36533	3695	16852	7833	2614	64870	31268	8721	119976	63248	14562

Notes: The highest values for each accessibility measure (e.g., auto-based access to retail) are shown in bold.

Accessibility disparities across income groups conform to expectations. The residential locations of various income groups are different. Specifically, higher-income groups tend to live in low-density suburbs where activity opportunities are sparse, so naturally their accessibility are relatively lower. By contrast, lower-income groups are likely to live in inner city where has abundant opportunities and good transit services (see Figure 2) and thus they tend to have high accessibility, especially by transit and walking. The overlays of accessibility maps and population distributions also confirm the above explanations. Places of greater non-work accessibility are generally consistent with high concentrations of lower-income population in the study area. The patterns are similar for accessibility to the four types of opportunities by the three transportation modes.

As mentioned above, a minor exception of the accessibility disparities is that the second-lowest income group ($25,000 to $49,999) has the highest automobile-based accessibility. The overlays of accessibility maps, population distributions, and transportation networks provide an answer for that. The second-lowest income group tends to live in the peripheral areas of the city and near highways (Figure 11), which can save time in entering highways and reaching regional destinations. However, such location patterns may raise concerns about environmental justice. Living proximate to highways means exposure to severe air pollution and noise, and thus increases health risks.

Figure 11. Distribution of the Second-lowest Income Group and Highways



Chapter 5. The Impacts of Non-work Accessibility on Travel Behavior

This chapter aims to answer the second research question: how does access to various opportunities affect travel to these opportunities? Section 5.1 presents descriptive analysis of non-work trips for the 2017 National Household Travel Survey (NHTS) WI-add on. Section 5.2 examines the effects of accessibility to four types of non-work destinations on two indicators of travel behavior: travel distance and travel mode.

5.1. Descriptive Analysis of Travel Data

This section describes non-work trips that originate from Milwaukee County by trip purpose and transportation mode. Table 6 summarizes the number of trips by origin and destination. Based on the 2017 NHTS data, the total number of non-work trips depart from Milwaukee is 1789, and 88.7% (=1587/1789) of these trips are made within Milwaukee County. This indicates that opportunities in Milwaukee County are generally sufficient to meet residents' daily demands. Indeed, Milwaukee is the regional hub of all types of services (Figure 6).

Table 6. Trips from Milwaukee (Origin) to Each County (Destination)

Destination	# Trip
Milwaukee	1587
Waukesha	141
Ozaukee	35
Washington	10
Racine	9
Kenosha	5
Walworth	2
Total	1789

People still travel to suburban counties. Waukesha is the most attractive destination with 141 trips. Based on Figure 6, East Waukesha has abundant opportunities and is adjacent to Milwaukee, likely attracting Milwaukee County residents to make trips. Milwaukee residents also travel to Ozaukee, Washington, Racine, and Kenosha, but the number of trips is limited. The

Milwaukee-Walworth route is the least popular one with only 5 trips in the dataset, probably because Walworth is far away from Milwaukee and offers very few opportunities.

Table 7 gives the statistics of trips by purpose and by transportation mode. The largest number of trips are for shopping, followed by recreation, meals, and healthcare. Automobile is the primary transportation mode for trips with all these four purposes. Trips by bicycle and transit are scarce in terms of both the absolute number and the percentage. Walking is a common non-automobile mode for non-work purposes except healthcare. 26.7% of recreational trips and 13.4% of dining trips are made on foot. The number of shopping tours by walking is 78, accounting for 10.1%. By contrast, there are only 4 walking trips to healthcare facilities, and the percentage is lower than 5%.

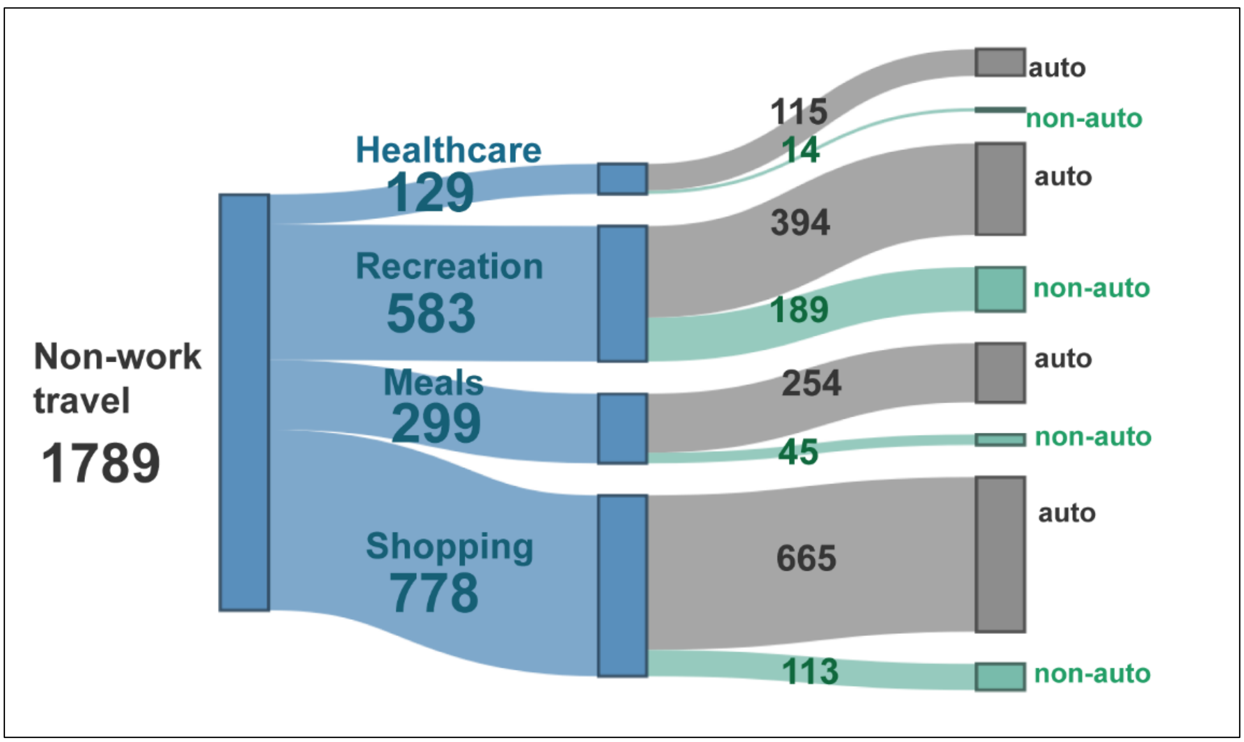
Table 7. Statistics of Non-work Trips

Purpose	Total	Mode	# Trip	% Trip	Average distance (mile)	Average time (min)
Healthcare	129	automobile	115	89.1	6.8	20.5
		bicycle	0	0.0	0.0	0.0
		transit	10	7.8	6.5	48.3
		walk	4	3.1	1.2	14.3
Recreation	583	automobile	394	67.6	6.8	17.6
		bicycle	15	2.6	2.5	22.7
		transit	18	3.1	3.9	39.0
		walk	156	26.7	0.7	14.4
Meals	299	automobile	254	84.9	4.6	15.7
		bicycle	2	0.7	0.7	15.7
		transit	3	1.0	2.3	34.4
		walk	40	13.4	0.4	13.7
Shopping	778	automobile	665	85.4	3.6	13.2
		bicycle	7	0.9	1.4	14.4
		transit	28	3.6	3.3	35.7
		walk	78	10.1	0.5	12.4

The average travel distance by walking is about 1 mile; walking is feasible and common for short-distance travel. Specifically, the average walking distance is 1.2 for healthcare, 0.7

miles for recreation, 0.4 mile for meals, and 0.5 miles for shopping. The shorter travel distance of dining and shopping trips is expected because the spatial distribution of food services and shopping opportunities tend to be more even than recreational facilities (Figure 6). The longer distance—1.2 miles— to reach healthcare facilities is not surprising. In fact, the travel distance of medical trips is the longest by all transportation modes. However, based on Figure 6a, healthcare opportunities are abundant. The reasons for such disparity are twofold. First, healthcare services have different types (e.g., preventive care, specialist office visit, and urgent care), which explains the large number of practitioners/opportunities in Figure 6a, therefore it is possible that the nearest opportunity is not the right type of medical service that patients are looking for. Second, factors like health insurance and doctors' prestige tend to complicate the process of choosing medical facilities.

Figure 12. Non-work Trips by Purposes and Modes



Given the small sample size of trips by transit, bicycling, and walking, this dissertation groups these three transportation modes into one category, non-automobile modes. Indeed, there are disparities in the average travel time/distance between these three modes. However, such in-category disparities are much less pronounced than the differences between non-automobile and automobile travel modes. Instead, non-automobile modes tend to be complementary to each other (Hanson & Giuliano, 2004, p.223). For example, it is common for transit riders to walk or bike to transit stops. Moreover, since the users of non-automobile modes are likely to be those who cannot afford automobile travel, previous research on transportation equity applied the same classification, revealing the disadvantages of non-auto trips and the privilege of automobile travel in car-dependent countries (Lee et al., 2018). Therefore, in this dissertation, trip mode is a binary variable (automobile or non-automobile) in the structural equation model. Figure 12 illustrates the sample size of trips by auto and non-auto modes for each type of non-work trips.

5.2. Impacts of Non-work Accessibility on Travel Behavior

This dissertation applies structural equation models to examine the accessibility-travel relationship while considering the influences of neighborhood built environment, psychological factors, and socioeconomic characteristics on travel behavior. Based on the conceptual framework, this dissertation hypothesizes four causal relationships from the four groups of predicting variables and three causal links between the four groups. This section discusses models results for two travel behavior indicators. In total, eight models (four types of non-work activities × two travel behavior indicators) have been tested. In each model, accessibility is the ratio of accessibility by walking to accessibility by automobile. Travel habits and density are used to represent psychological factors and the built environment, respectively. Variables are described in detail in Chapter 3.

Research that applies structural equation models reports two types of results: the effects of endogenous variables on endogenous variables and the effects of exogenous variables on endogenous variables. In this dissertation, accessibility, density, travel habits, and travel behavior are endogenous, meaning that their values are dependent on other variables in the model, whereas socioeconomic characteristics are exogenously determined. Therefore, in the following subsections, the effects of accessibility, density, and travel habits on travel behavior indicators are first presented, and the effects of socioeconomic characteristics on travel are given in a separate table.

5.2.1. Travel Distance

Table 8 reports the standardized effects of accessibility, habits, and density on travel distance. Standardized coefficients show how many standard deviations the dependent variable changes when independent variables increase or decrease by one standard deviation. Since the changes are expressed in the units of standard deviation, standardized coefficients are commonly used to compare the magnitude of the effects of variables in the same model, and higher absolute values mean stronger effects.

Figure 13 takes shopping activity as an example to illustrate the relationships among endogenous variables. The standardized coefficients of accessibility to retail opportunities and density are -0.198 and -0.089, respectively, showing the stronger effects of accessibility than density. The total effect of habits on travel distance is -0.135, which is the sum of direct effect (-0.093) and indirect effect mediated by density (-0.042= -0.089*0.476). This means that the habits of using non-automobile modes reduces travel distance in a straightforward and effective way.

Figure 13. Illustration of Path Coefficients (Shopping)

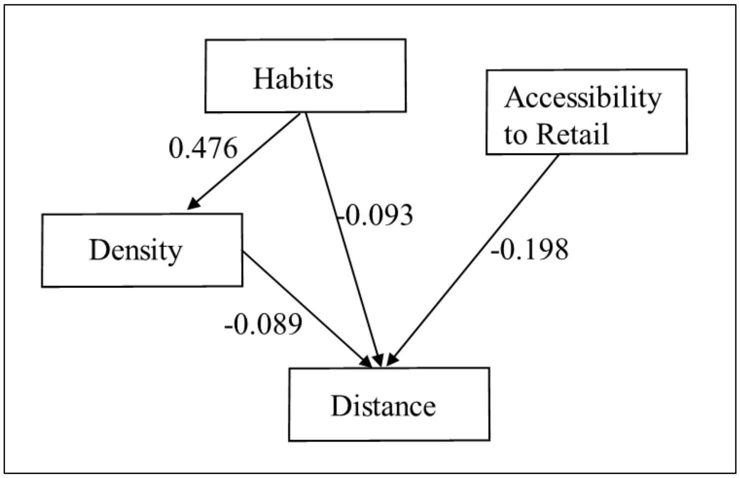


Table 8. Standardized Effects of Accessibility, Habits, and Density on Travel Distance

	Effect	Accessibility	Habits	Density
Retail (N=778)				
Density	Direct	/	0.476	/
Distance	Direct	-0.198	-0.093	-0.089
	Total	-0.198	-0.135	-0.089
Recreation (N=583)				
Density	Direct	/	0.497	/
Distance	Direct	-0.270	-0.110	-0.210
	Total	-0.270	-0.214	-0.210
Food services (N=299)				
Density	Direct	/	0.239	/
Distance	Direct	-0.385	-0.176	-0.237
	Total	-0.385	-0.232	-0.029
Healthcare (N=129)				
Density	Direct	/	0.105	/
Distance	Direct	-0.432	-0.136	
	Total	-0.432	-0.136	

Notes: only significant effects are shown in the table.

The results of the four models are consistent: accessibility has negative impacts on travel distance for all four types of activities. For example, people living in places of higher accessibility to retail are more likely to make shorter shopping trips. Likewise, as accessibility to other destinations increases, the distance of respective trips is likely to decrease. The finding is reasonable: higher accessibility enables people to find the desired destination nearby from abundant choices and hence can shorten travel distance. Indeed, all else being equal, if people can fulfil their needs, such as seeing a doctor and buying goods, at closer locations, they are less likely to make long-distance trips to destinations located farther away.

Additionally, density and travel habits also play a role in affecting travel distance. Residential density, which captures land use at the neighborhood/census tract level, has significant effects on the distance of non-work travel except for healthcare trips. Travel habits have both direct and indirect effects through the mediating variable—density—on travel distance. Specifically, those who have the habits of using non-automobile modes are likely to make short-distance travel to non-work destinations, and meanwhile they tend to live in communities with high-density land use and such built environment characteristics are found to reduce travel distance.

Further, this dissertation examines disparities in accessibility effects on various non-work trips. Comparisons of standardized coefficients may not achieve this goal because standardization requires sample variance; however, different models have different variances. Therefore, this dissertation compares the unstandardized coefficients of accessibility across the four models.

Table 9 reports unstandardized effects. The model results reported in table 9 indicate that the effects of accessibility on travel distance vary by trip purposes. Specifically, the unstandardized direct/total effect of accessibility on travel distance is the largest for dining trips (-9.868), followed by healthcare (-7.944) and shopping (-5.492), and the smallest for recreation (-2.144).

Table 9. Unstandardized Effects of Accessibility, Habits, and Density on Travel Distance

	Effect	Accessibility	Habits	Density
Retail (N=778)				
Density	Direct	/	3.022	/
Distance	Direct	-5.492	-0.109	-0.015
	Total	-5.492	-0.154	-0.015
Recreation (N=583)				
Density	Direct	/	3.526	/
Distance	Direct	-2.144	-0.294	-0.053
	Total	-2.144	-0.481	-0.053
Food services (N=299)				
Density	Direct	/	5.213	/
Distance	Direct	-9.868	-0.168	-0.029
	Total	-9.868	-0.319	-0.029
Healthcare (N=129)				
Density	Direct	/	0.538	/
Distance	Direct	-7.944	-0.099	
	Total	-7.944	-0.099	

Notes: only significant effects are shown in the table.

The above findings generally conform to expectations. As discussed in the literature review chapter, travel is derived, and thus sensitive to the changes in travel costs, i.e., accessibility, and theoretically, the price elasticity is not identical for all types of trips (Button, 2010, p.85). The model results have shown that accessibility has significant impacts on travel distance for all the four types of non-work trips, and the unstandardized coefficients of accessibility in the four models are different, which confirms the significant but varying effects of accessibility on non-work travel.

The magnitudes of accessibility effects are slightly different from expectations. Theoretically, the availability of substitutes for potential destinations and the importance of the activities at destinations influence people's intention on whether or not to reduce travel costs to achieve maximum utility (Button, 2010, p.85). Therefore, accessibility to food services and retail is expected to have large impacts on travel since the differences among the same type of stores and restaurants could be relatively small. By contrast, accessibility to recreation is expected to have moderate impacts on travel. People visit different types of recreational facilities, although some recreational facilities can be substitutable. As a result, it is likely that people care about travel costs to recreational destinations, hence accessibility is significant, but people may be less keen to minimize recreation travel costs compared to shopping and dining trips. The empirical results are consistent with the above hypothesis, confirming the more elastic effects of accessibility to food and retail than to recreation.

However, the empirical evidence on the effects of accessibility to healthcare is different from theoretical expectations. It is expected that accessibility to healthcare opportunities has the smallest impacts on travel among the four types of non-work trips. Medical treatments are important and expensive, so compared to the financial costs and potential benefits of health checkups or treatments, people might be less concerned about the travel costs of medical trips. Surprisingly, the model results suggest that accessibility to healthcare has larger effects on travel distance than to retail and recreation. I suspect two reasons. On the one hand, medical trips tend to be more time-sensitive than shopping and recreation trips. That is, when people are sick, they are willing to see healthcare providers as soon as possible, whereas shopping and recreation trips are relatively time-flexible. On the other hand, there are a wide range of healthcare services, such as primary care, urgent care, and emergency rooms, so the potential destinations for healthcare services are actually highly substitutable under certain circumstances. For example, people can visit nearby healthcare facilities (e.g., urgent care and ER) instead of the primary care provider's office that located far away when they urgently need to see a doctor.

The indices of all the four travel distance models demonstrate good model fit. Table 10 gives model fit indices and corresponding reference values.

Table 10. Fit Indices of Travel Distance Models and Reference Values

Model fit index	Reference value	Retail	Recreation	Food	Healthcare
Degree of freedom		11	9	16	16
Comparative Fit Index (CFI)	>0.9	0.951	0.934	0.987	0.928
Tucker-Lewis index (TLI)	>0.9	0.987	0.958	0.996	0.978
Root Mean Square Error of Approximation (RMSEA)	<0.05	0.024	0.019	0.025	0.038

Sociodemographic characteristics are expected to influence accessibility, travel habits, and travel behavior based on the conceptual framework. Note that not all the six exogenous variables are hypothesized to influence accessibility, travel habits, and distance. The hypothesized relationships are constructed based on literature. Table 11 gives model results. Only significant effects are shown, and the effects of sociodemographic characteristics on travel distance are highlighted.

Household income shows significant effects on the distance of non-work travel. Specifically, individuals from wealthier households tend to make longer-distance non-work trips. As the wealthier tend to be less sensitive to travel costs, they may not always travel to the nearest opportunities to fulfill their needs. It is possible for them to make long-distance trips to attend concerts, visit restaurants, and conduct other activities instead of choosing the nearest ones. But one exception is healthcare trips. Table 11 shows that household income has insignificant impacts on the distance of healthcare trips. Indeed, regardless of income, people want to receive immediate medical treatments when they are sick. So, those with higher household income are unlikely to make long-distance travel for healthcare as long as they can find healthcare services at closer locations.

Table 11. Standardized Effects of Sociodemographic Variables on Accessibility, Habits, and Travel Distance

	Gender	Race/ethnicity	Youth	Education	Household income	Household size
Retail						
Accessibility					-0.035	
Habit	/	0.080	/	/	-0.141	
Distance					**0.053**	
Recreation						
Accessibility			/		-0.138	
Habit			0.084		/	
Distance		/			**0.034**	
Food services						
Accessibility			0.113		-0.156	
Habit				0.202		
Distance	0.016				**0.098**	0.068
Healthcare						
Accessibility					/	
Habit		/				
Distance					/	

Notes: only significant effects are shown in the table; blank cell indicates no hypothesized relations in the model; '/' represents hypothesized but insignificant relations.

5.2.2. Non-auto Travel

Table 12 reports the standardized effects of accessibility, habits, and built environment density on travel mode. Travel mode is a binary variable in the model, with '1' for non-automobile travel and '0' for automobile travel.

Results show that the effects of accessibility on travel mode vary by the types of non-work opportunities. The coefficients of accessibility are significant for recreation and food services but not for retail and healthcare, meaning that higher accessibility to recreational facilities and food services increases the probability of using non-automobile modes for the respective trips, whereas accessibility to retail and healthcare do not show such effects.

Table 12. Standardized Effects of Accessibility, Habits, and Density on Transportation Mode

		Accessibility	Habits	Density
Retail (N=778)				
Density	Direct		0.469	
Non-auto travel	Direct		0.520	0.045
	Total		0.541	0.045
Recreation (N=583)				
Density	Direct		0.493	
Non-auto travel	Direct	0.316	0.218	0.115
	Total	0.316	0.274	0.115
Food services (N=299)				
Density	Direct		0.415	
Non-auto travel	Direct	0.639	0.259	0.111
	Total	0.639	0.305	0.111
Healthcare (N=129)				
Density	Direct			
Non-auto travel	Direct			
	Total			

Notes: only significant effects are shown in the table.

Table 13. Unstandardized Effects of Accessibility, Habits, and Density on Transportation Mode

		Accessibility	Habits	Density
Retail (N=778)				
Density	Direct		3.022	
Non-auto travel	Direct		0.633	0.010
	Total		0.663	0.010
Recreation (N=583)				
Density	Direct		3.528	
Non-auto travel	Direct	3.238	0.338	0.017
	Total	3.238	0.397	0.017
Food services (N=299)				
Density	Direct		4.021	
Non-auto travel	Direct	8.959	0.538	0.044
	Total	8.959	0.715	0.044
Healthcare (N=129)				
Density	Direct			
Non-auto travel	Direct			
	Total			

Notes: only significant effects are shown in the table.

Table 13 reports unstandardized effects. Again, significant unstandardized coefficients across models can be compared to show the disparities in accessibility effects. The coefficients of accessibility in the food services and recreation models are 8.959 and 3.238, respectively, showing that increases in accessibility to food services are more likely to encourage non-automobile travel.

The differing effects of accessibility on travel mode (non-automobile travel or not) are expected. Travel costs (e.g., time, physical efforts) and convenience are found to influence the choice of travel mode (Schneider, 2013). Higher accessibility tends to reduce trip planning time for non-automobile travel, and shortened planning time, associated with lower travel costs, can increase the competitiveness and hence the likelihood of using non-automobile modes. The empirical results suggest that accessibility has no direct effects on non-automobile modes for healthcare and retail trips. As mentioned earlier, medical visits are often time-sensitive. Even for routine checkups, arriving on time is essential to avoid appointment cancellations. In situations that people are ill, they cannot take buses, bike, or walk to healthcare facilities. Besides, people need to carry goods on their shopping trips. For these reasons, automobile travel, which is advantageous in terms of convenience, is usually preferred for healthcare and shopping trips. In contrast, dining and recreation trips can be more time-flexible and physically relaxed, and thus high accessibility to these opportunities increases the likelihood of using non-automobile modes.

Further, the relationship between accessibility and travel mode is stronger for food services, which is reasonable. In the study area, food services are more likely to locate at places with higher-density land use, such as downtown, near office buildings and universities (see Figure 6). Such locations tend to be pedestrian- and cyclist-friendly and have transit services, encouraging the adoption of non-automobile modes.

Additionally, the effects of density and travel habits on travel mode also vary across different non-work trips. Habits of using non-automobile modes encourage the adoption of non-automobile modes for shopping, recreation, and dining trips but not for healthcare trips. Similarly, people living in high-density communities are likely to make non-automobile travel except for seeking healthcare. Consistent with the discussion above, medical trips are special in the four groups of non-work trips. Built environment characteristics and psychological factors are not likely to encourage non-automobile travel to medical opportunities. Instead, people tend to be persistent in automobile use for healthcare purposes.

Interestingly, accessibility, which captures land use at the regional level, does not encourage non-automobile travel to retail opportunities, but density, which reflects land use at the neighborhood level in this research, shows significant impacts on the adoption of non-automobiles modes for shopping trips. The finding is reasonable. People tend to visit regional opportunities that are often far away from residential areas when they have a long shopping list or need some items that are not sold at local stores, such as large appliances. Walking and bicycling tend to be infeasible to reach remote destinations and taking transit seems inconvenient under such circumstances. However, trip distances in high-density communities tend to be short and within reasonable walking or biking distance. Besides, people are likely to visit local stores when their shopping needs are simple or basic, such as buying a book or personal care products, and these items are easy to carry while walking and bicycling.

Table 14 gives model fit indices and corresponding reference values. All the fit indices demonstrate good model fit.

Sociodemographic characteristics also play a role in affecting travel mode. Table 15 provides the effects of sociodemographic variables on non-auto travel. Only significant effects are shown, and the effects of sociodemographic characteristics on travel mode are highlighted. Still, household income shows significant impacts. As household income increases, people are less likely to make non-automobile travel to retail opportunities, recreation facilities, and food services. Additionally, youth (15-24 years old) tend to rely on non-automobile modes for shopping and recreation rather than dining and seeking healthcare.

Table 14. Fit Indices of Travel Mode Models and Reference Values

Model fit index	Reference value	Retail	Recreation	Food	Healthcare
Degree of freedom		11	17	18	12
Comparative Fit Index (CFI)	>0.9	0.974	0.940	0.984	0.969
Tucker-Lewis index (TLI)	>0.9	0.993	0.980	0.992	0.992
Root Mean Square Error of Approximation (RMSEA)	<0.05	0.029	0.023	0.045	0.018

Table 15. Standardized Effects of Sociodemographic Variables on Accessibility, Habits, and Travel Mode

	Gender	Race/ethnicity	Youth	education	Household income	Household size
Retail						
Accessibility					-0.024	
Habit	0.071	0.105			-0.135	
Non-auto travel			**0.104**		**-0.118**	**-0.089**
Recreation						
Accessibility			0.070		-0.127	
Habit			/			
Non-auto travel			**0.128**		**-0.159**	
Food services						
Accessibility			0.162		-0.204	
Habit	/			0.221		
Non-auto travel			/		**-0.040**	/
Healthcare						
Accessibility						0.211
Habit			0.280			
Non-auto travel	/		/		/	

Notes: only significant effects are shown in the table; blank cell indicates no hypothesized relations in the model; '/' represents hypothesized but insignificant relations.

Chapter 6. Conclusion

6.1. Summary of Findings

6.1.1. Accessibility to Non-work Destinations

This dissertation examines the patterns of accessibility to four types of non-work opportunities in the region by three transportation modes. Differences are observed among accessibility to healthcare, recreation, food services, and retail by the same travel mode, due to the location patterns of these opportunities. Moreover, non-work accessibility by the three transportation modes exhibits different geographic patterns. Walking-based and automobile-based accessibility are both highest in the central parts of Milwaukee County and decline away from the center, but the spatial ranges of places of high automobile-based accessibility tend to be larger. Transit-based accessibility is highest in downtown Milwaukee and decreases along transit lines towards the west, south, and north sides.

This dissertation shows that disparities in non-work accessibility exist across different racial/ethnic groups and income groups. Consistent with expectations, racial/ethnic minorities and lower-income groups generally have higher non-work accessibility than their counterparts. Explanations can be that racial/ethnic minorities are likely to concentrate in certain neighborhoods in and near downtown where opportunities and transportation services concentrate. In particular, Blacks tend to experience severe residential segregation that constrains them in the city. Lower-income groups have high accessibility to all four types of non-work opportunities by the three transportation modes, and accessibility tends to decrease as personal annual income increases. Similarly, lower-income groups are likely to live in the city, whereas higher-income groups tend to live in low-density places, away from the city center.

Moreover, this dissertation overlays the spatial pattern of accessibility with population distributions. Overlay maps identify the spatial gaps between accessibility and concentrations of the Black population. Black residents who live on the far north side away from downtown have relatively poor accessibility, and their situation could be overlooked if only examining the weighted average accessibility for all Black residents as a whole. Besides, overlay maps find that the second-lowest income group ($25,000 to $49,999) tends to live in the peripheral areas of the city and near highways, which can explain their high accessibility by automobile but also raises concerns about environmental justice.

Findings of this dissertation suggest that in general, potentially disadvantaged groups have better non-work accessibility by both automobile and non-automobile modes than their counterparts. Although the current situation looks good, some problems (e.g., in-group disparities in accessibility and environmental injustice) appear and need policy and planning interventions.

6.1.2. The Impacts of Accessibility on Travel

To understand how accessibility affects non-work travel, this dissertation investigates the effects of accessibility to four types of non-work opportunities on two indicators of travel behavior: travel distance and travel mode (non-auto travel or not). Results suggest that the effects of non-work accessibility on travel behavior are significant and vary by the types of opportunities. Specifically, higher accessibility to non-work opportunities is likely to reduce the distance of the respective trips. Furthermore, the accessibility effects on travel distance are the largest for food services, followed by healthcare and retail, and the smallest for recreation. Additionally, improvements in accessibility to food services and recreation encourage non-work travel, whereas increases in accessibility to healthcare and retail do not show significant impacts.

This dissertation also identifies that density and travel habits show differences in the impacts on travel behavior. Sociodemographic characteristics also play a role. In particular, household income has significant and consistent impacts on travel for non-work purposes except for healthcare.

6.2. Policy and Planning Implications

This section discusses planning and policy implications based on the main findings of this research.

First, this dissertation suggests that there are differences in non-work accessibility within the same population groups. This dissertation identifies places that have large concentrations of the Black population but low accessibility to non-work opportunities. These Black neighborhoods tend to be overlooked because the Black population as a whole has better accessibility than other racial/ethnic groups. Thus, planning needs to consider such in-group differences and should particularly focus on minority neighborhoods whose accessibility is below the average of the same minority groups.

Second, environmental injustice may exist in lower-income communities, requiring policy attention. This dissertation finds that the low-income group with an annual income between $25,000 and $49,999 has the highest accessibility to non-work opportunities by automobile, probably because their residential locations are proximate to highways. However, such locations may raise environmental and health concerns because residents are exposed to severe air pollution and noise, which increases health risks.

Third, this dissertation lends support to the implementation of accessibility-based planning toward various non-work activities. The higher accessibility, the fewer travel barriers that individuals need to overcome to reach desirable opportunities. Otherwise, long-distance travel and excessive automobile travel would affect the quality of life. Commonly, accessibility-based planning strategies focus on job accessibility and consequently promote job-housing balance to reduce commuting burden. This dissertation finds that accessibility to non-work opportunities has significant effects on the reduction of travel distance and adoption of non-automobile modes for non-work trips, suggesting the feasibility of implementing accessibility-based strategies with respect to non-work opportunities. Since non-work trips account for a large share of daily trips, reducing the burden for non-work travel would make a significant contribution to individuals' wellbeing.

Nevertheless, it is important to distinguish the type of activities while implementing accessibility-based policies. Findings of this dissertation suggest that food services deserve great attention in terms of the travel effects of access to food. This dissertation finds that increases in accessibility reduce the distance of trips for food to a greater extent than other trip purposes. In addition to shortened travel distance, improving accessibility to food services is more likely to encourage non-automobile modes than all the other types of opportunities. Accordingly, land use and transportation planning should develop strategies that can increase accessibility to restaurants and food-related opportunities. Even though trips for food purposes do not account for the largest share of non-work trips based on the National Household Travel Survey for the year 2001, 2009, and 2017, research found that the number of trips to restaurants has increased, and this trend is likely to continue as people tend to cook less at home (Robson et al., 2016). Therefore, this dissertation recommends focusing on accessibility improvements for food services in future land use and transportation plans.

Additionally, this dissertation identifies that higher accessibility to recreational facilities can also increase the probability of using non-automobile modes, although the magnitude of accessibility effects for recreation is lower than that of food services. However, compared to food services, trips for recreation constitute a greater proportion of non-work trips, so the increase in non-automobile use might be larger. Thus, land use and transportation planning may also consider strategies related to accessibility improvements for recreational opportunities if promoting ridership or encouraging walking and bicycling are primary planning objectives.

Fourth, this dissertation suggests that providing transportation means, primarily for automobile travel, for healthcare trips is necessary. Findings of this dissertation reveal that accessibility has no effect on promoting non-automobile travel for healthcare trips. Rather, people tend to persist in automobile travel to reach healthcare opportunities. Possible explanation can be that for routine checkups, automobile travel is reliable in terms of travel time, and it is also convenient when people are ill. Therefore, alternatives such as subsidizing automobile trips (e.g., ridesharing trips) might be helpful to those who are from auto-less households and thus have difficulties reaching healthcare opportunities by automobile.

6.3. Limitations and Future Research

6.3.1. Other Travel-related Factors

This dissertation does not specifically control for vehicle ownership because sociodemographic characteristics are exogenous variables in my statistical models, but vehicle ownership is affected by other factors and thus is not exogenous. Nevertheless, the statistical models contain sociodemographic variables that are significant predictors for vehicle availability, education levels and household income. In this way, this dissertation partly controlled for vehicle ownership while predicting travel behavior.

This dissertation focuses on major factors that shape travel behavior, including land use patterns, transportation services, sociodemographic characteristics, and psychological variables. In the real world, many other factors can influence individual's decision on activity destinations and subsequently travel behavior. For example, price and marketing strategies affect customers' choices of stores (Mulhern & Leone, 1990): sales and coupons are likely to attract people.

Likewise, health insurance plays a role in the selection of medical care sites. People usually select a healthcare provider based on a list of in-network doctors provided by insurance companies. Other factors such as health conditions on the travel day, gasoline price, and carrying bags or not, particularly while shopping, are also likely to affect travel behavior, such as transportation mode choice. These factors are not included in the framework of this dissertation because data sources do not include and cannot be linked to the information. Moreover, this dissertation acknowledges that some random factors, such as roadworks and reckless driving on certain streets, could also influence travel. Future research will include more travel-related variables in the statistical models and conduct qualitative research to explore factors that affect travel but cannot be statistically controlled.

6.3.2. Differences between Non-auto Modes

With limited sample size, this dissertation does not capture the differences between multiple types of non-automobile modes (e.g., walking, bicycling, and transit). Future research will distinguish walking, bicycling, and if possible, multiple transit services to improve the understanding of accessibility effects on the choice of travel mode. Conducting a local transportation survey might be needed to fulfill this goal.

6.3.3. Detailed Trip Purposes

This dissertation examines the effects of accessibility on four major types of non-work travel (healthcare, recreation, eating out, and shopping), without further disaggregating trips for each major type. This is because the travel survey only provides data for the main types of travel purposes. Accordingly, this dissertation uses 2-digit NAICS sectors (healthcare, recreation, food services, and retail trade) to calculate accessibility. This dissertation acknowledges that travel behavior might be different when distinguishing trips by more detailed trip purposes, and future research will explore the relationship between accessibility and travel for more specific non-work trip.

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