Older Adult Active Transportation

in Massachusetts

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Abstract

Active transportation can facilitate healthy aging through improved mobility and physical health. Living in a walkable environment is linked to increased active transportation among older adults. Yet there is a gap in research on active transportation and its relationship to walkability among older adults living in Massachusetts. My research addresses this gap through descriptive GIS mapping and quantitative analysis of age-based trends in transportation using data from the 2010-2011 Massachusetts Travel Survey (MTS) and Walk Score®. The main findings were that overall travel and rates of active transportation tended to decrease with age ($p<0.01$). ZIP codes with higher Walk Scores® also had higher rates of walking for both younger and older adults. Though these results cannot establish causation, they can be useful in efforts to make neighborhoods friendlier to older adult pedestrians.

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Chapter 1: Introduction

Aging challenges us. As we age, what once came easily may become more difficult. Adapting to our diminished physical and mental capacity can be difficult. Aging is also hard for those of us who have not yet reached old age: it is hard to lose an older friend or family member, or to witness their sometimes painful decline. Furthermore, due to age-related health issues, there comes a time, for most, when it is not possible to live independently. This dependence puts additional burdens on healthcare and service providers, communities, and government programs; it also increases healthcare spending (CDC 2013). Dependence and eventual death in old age are perennial "facts of life." But now, as our largest generation, the baby-boomers, become senior citizens, we face an unprecedented public health problem with aging, both across the nation and here in Massachusetts.

As a state, as communities and as individuals, we can take steps to promote "healthy aging." For instance, the Massachusetts Healthy Aging Collaborative (2014) recommends that individuals practice six healthy aging behaviors: eating a healthy diet, maintaining close relationships and having a social life, being physically active, tending to mental/spiritual health, understanding and managing health conditions, and establishing/maintaining secure finances and housing. Communities can foster healthy aging by providing the physical and social infrastructure to facilitate healthy behaviors (Massachusetts Healthy Aging Collaborative 2014). Examples include affordable housing for older adults, health services, senior centers, recreation facilities, and safe, walkable neighborhoods.

My research investigates a particularly compelling healthy aging strategy: walking and bicycling. Walking and bicycling contribute to healthy aging as forms of physical activity and exercise. They also facilitate health as modes of transportation:

transportation is needed in order to access the services to stay healthy and connected. Compared to other forms of either transportation or exercise, walking and bicycling are among the least expensive and most accessible. Walking and bicycling are, therefore, a cost-effective healthy aging strategy.

Whereas the state plan on aging (Executive Office of Elder Affairs 2013) and the Massachusetts Healthy Aging Report (2014) underscore the importance of physical activity and transportation to healthy aging, research specifically on walking and bicycling among older adults in Massachusetts is lacking. For instance, the American Community Survey (ACS) data for Massachusetts provide rates of active transportation, but only for the commuting trips of the workforce. The ACS data on transportation therefore largely exclude the older population. Furthermore, the Massachusetts Travel Survey (MTS 2010-11) estimates active transportation and recreational bicycling across the state, but the published analyses do not explore any age-based differences.

My research, in characterizing older adult walking and bicycling in Massachusetts, will address a little-studied topic. There are four main objectives of my research. First, in order to put my subsequent findings in context, I will create maps depicting the spatial patterns in the geographic distribution of older adults across the state. The other three objectives look at the age-based trends in walking and bicycling in Massachusetts. In Objective 2, I explore whether different age groups differ in the amount of traveling they do (trip rate) and in the modes of travel they use (mode share). Objective 3 looks at age-based trends in bicycling, both for recreation and transportation. I will investigate, in Objective 4, whether the relationship between living in a walkable neighborhood and walking for transportation differs based on age.

This research will contribute to efforts to facilitate healthy aging through walking and bicycling. Furthermore, it will be useful to service providers, planning departments, and advocates for older adult-friendly streets and neighborhoods.

Chapter 2: Literature Review

The goal of my thesis is to characterize older adult walking and bicycling in Massachusetts. Prior to exploring my four main research objectives, I will review existing literature and current data related to my topic. In this literature review, there are three over-arching themes: an overview of challenges and resources vis-à-vis healthy aging; links between walking/bicycling and healthy aging; and how neighborhood design can facilitate older adult walking/bicycling.

The Public Health Challenge of Aging: Nationwide and in Massachusetts

The scale of our public health challenges related to aging, both nationally and in Massachusetts, is considerable. From 2013 to 2038, the population of Americans aged 65 year or older is expected to double (CDC 2014). By 2030, 20% of the entire population will be over the age of 65 (CDC 2014). Common challenges of old age include declines in physical ability (Sallis 2000), increased susceptibility to illness (Gardner 1980), and dementia and Alzheimer's disease (NIA 2013). Therefore, forecasters predict that this demographic shift will lead to an increase in disabilities, health conditions, and chronic diseases for the US population as a whole (National Academy on an Aging Society 1999). Furthermore, the greater number of older, chronically ill adults is expected to lead to a 30% increase in overall healthcare spending by 2030 (CDC 2014). Medicare spending is expected to increase from $555 billion in 2011 to $903 billion in 2020 (CDC 2014).

According to the Massachusetts Healthy Aging Collaborative (2014), which tracked healthy aging indicators at the state, regional, and community level, the Commonwealth is no exception to the national demographic shift. For instance, while older adults made up 14% of the state's population in 2010, they will account for 21% in 2030. Massachusetts was ranked the fourth healthiest state in the nation, based on older

adult health indicators, but health problems are still prevalent among older adults in the state. Almost half of Massachusetts adults over age 75 have a disability and about a third of those in the 65-74 age range are disabled, compared to lower rates at all younger age ranges (BRFSS 2013, cited in MDPH 2014). High blood pressure, physical inactivity, diabetes, heart disease and stroke, pulmonary disease, arthritis, and lifetime cancer diagnoses are more prevalent in older adults than younger adults in Massachusetts (BRFSS 2013, cited in MDPH 2014). For some diseases related to aging, such as hypertension, depression, Alzheimer's disease and dementia, Massachusetts ranks below the rest of the nation (Massachusetts Healthy Aging Collaborative 2014). However, there is substantial variability within Massachusetts, with communities such as New Bedford, Springfield, Fall River, Worcester, Lowell, and South Boston faring considerably worse on multiple indicators of older adult health.

Walking, Bicycling, and Healthy Aging

Walking and bicycling contribute to healthy aging through two pathways: first as a form of transportation that improves mobility and access to services and second as a form of physical activity that improves physical and mental health.

Mobility and Healthy Aging

Mobility, or "the ability to move around effectively and safely in the environment," is a key component of healthy aging (CDC 2014, 35). Whether through walking or any other form of transportation access, mobility is a cornerstone of the AARP's concept of "livable communities" for older adults: "a livable community is one that has affordable and appropriate housing, supportive community features and services, and adequate mobility options, which together facilitate personal independence and the engagement of residents in civic and social life" (Kochera et al. 2005, 4). According to the Centers for Disease Control (2014), low mobility is linked with adverse health

outcomes including depression, cardiovascular disease, cancer, greater risk of injuries from falls and automobile crashes, and increased risk of death. Mobility is a prerequisite of "healthy aging" as defined by the Massachusetts Health Aging Collaborative (2014), which identifies six ingredients to healthy aging: eating a healthy diet, maintaining close relationships and having a social life, being physically active, tending to mental/spiritual health, understanding and managing health conditions, and establishing/maintaining secure finances and housing. Many of these healthy behaviors typically occur outside of the home, so having a reliable form of transportation is necessary. Examples of healthy behaviors that require mobility and transportation include buying healthy food, attending social events, and visiting health care providers to manage chronic conditions.

In all but the most walkable and public transit accessible areas, mobility often requires access to a car and ability to drive, which puts older non-drivers at a disadvantage in regard to healthy aging. Not surprisingly, aging is linked with fewer trips outside of the home (Farber et al. 2011). Most of us, once we reach a certain age, will stop driving: the average 75 year old woman will have at least ten years of non-driving; for men, this figure is six years (Gibson et al. 2004, cited in Kochera et al. 2005). About 21% of Americans over 65 years of age do not drive; this statistic is the same within Massachusetts (NHTS 2000, cited in Bailey 2004). More than half of these older non-drivers do not normally leave their home (Bailey 2004). Their lack of mobility is linked to 15% fewer trips to the doctor and 65% fewer trips for social, family, and religious activities.

Lower levels of contact with others are, in turn, associated with depression and lower emotional well-being among older adults. More than half of older adults who reported not having traveled outside the home in the past week also reported that they wished they could get out of the house more often (Lynott and Figueiredo 2011). A survey of older drivers and non-drivers found that drivers scored higher on various

indicators of healthy aging, such as having a “high quality of life,” “being involved in people and the world around me,” “being able to take care of myself,” and not “frequently feel[ing] isolated from other people” (Kochera et al. 2005). Yet non-drivers living in walkable urban areas with better public transportation fared far better on these measures of satisfaction, quality of life, and access to services than their counterparts in less walkable, more spread out regions.

Many of those older adults who continue to drive may be putting themselves at risk: the vision, physical function, and cognitive declines that often go along with age can be detrimental to driving ability (Phillips et al. 2006). Drivers over age 65 face higher risks per mile driven of being in an accident (Kochera et al. 2005). Crashes at intersections, when making left turns, and merging, exiting, or changing lanes on limited access highways are more likely to occur among older drivers (Federal Highway Administration 2001). Due to increased frailty, older drivers (above 75) are also more likely than younger drivers to suffer fatal injuries in a car crash (Li e al. 2003, cited in Bailey 2004).

It may be beneficial for older adults facing difficulty with driving to find mobility through alternative means of transportation. One solution is to be driven by another. Being driven by someone else is the most common form of transportation among older non-drivers (Kochera et al. 2005). It can allow older adults to travel farther than they could using active transportation. Yet walking and bicycling may, for some older adults, and at some times, be preferable to being driven. While being driven by another is not possible when nobody else is available to drive, walking and bicycling are possible anytime when conditions outside are safe. Older adults often don’t want to impose upon others or don’t ask for rides due to feelings of dependency (Stowell Ritter et al. 2002). By contrast, improved mobility through active and public transportation can foster improved quality of life and a sense of independence among older adults who can no longer drive

(Kochera et al 2005; CDC 2009). Being driven, using public transit or paratransit are the only options for those older adults who no longer have the physical ability to walk. But for those who can still walk or bicycle, regularly using active transportation has the co-benefit of helping to maintain or improve physical health, as will be discussed in greater detail later (Huy et al. 2008; Vellas et al. 1997). Though not feasible for all older adults in all places, active transportation is a healthy alternative to driving that allows older adults to enjoy the benefits of mobility and independence.

In a recent survey of adults over 45, more than half responded that living somewhere where it is easy to walk was "extremely" or "very important" to them (Keenan 2010, 1). Being in a walkable neighborhood was seen as less important than being near friends, family, and destinations (such as grocery stores and doctors' offices) but was seen as more important than being near good schools, work, or transit. The preference of walking over public transportation is in line with existing research indicating that walking is far more common among older adults than public transit ridership (Lynott and Figueiredo 2011). For those older adults who do live in areas served by public transit, it is typically necessary to walk or bicycle from one's origin to the public transit stop, and then from the transit stop to one's destination. Active transportation, whether as part of a multi-modal transit system in more urban areas, or in rural areas as the primary alternative to car transportation, is an important way for older adults to access the services necessary for healthy aging and to maintain mobility and independence in older age.

Rates of Walking, Bicycling, and Active Transportation

Before discussing the second link (via physical activity) between walking or bicycling and health, I will take a step back and explore the data on the prevalence of walking and bicycling, and how these statistics vary by country, gender, age, and income.

Statistics suggest, with some exceptions, that Americans, particularly older Americans, have lower levels of both overall physical activity, and specifically walking, bicycling, and active transportation. Within the United States, 10.4% of all transportation trips are walking trips and 1% are bicycling trips, with these rates being somewhat higher in large cities (NTHS 2009, cited in Alliance for Biking & Walking 2014). Transportation walking rates are not different between men and women, but transportation bicyclists are more likely to be men: only 24% of these bicycle trips were taken by women. Low-income earners are more likely than higher earners to be pedestrians. Rates of transportation bicycling, however, are not different according to income. In general, older adults engage in less physical activity than middle-aged adults (BRFSS, cited in Lynott and Figueiredo 2009). Among both rural and urban women over 40, older age was associated with less leisure time physical activity (Wilcox et al. 2000). In a similar vein, a study of urban adults found that older adults (over 60 years old) tended to both walk less and get less overall physical activity than younger adults (Hillier et al. 2014).

Consistent with the prevailing physical activity trends, older adults also engage in less active transportation than younger adults. While older adults make up 13% of the U.S. population, they represent only 10% of all transportation walking trips and 6% of all transportation bicycling trips (NHTS 2009, cited in Alliance for Biking and Walking 2014). Transportation walking among adults over 65 declined significantly between 2001 and 2009 according to the National Household Travel Survey (Pucher et al. 2011). These trends are less pronounced and in fact may go in the opposite direction for recreational physical activity. The National Household Travel Survey found older adults spent more minutes per day engaged in recreational, as opposed to transportation, walking and bicycling (USDOT 2010). A survey of six small cities in the U.S. found that older age was positively associated with engaging in more weekly miles of recreational bicycling

but that there was no significant relationship between age and weekly miles of transportation bicycling (Xing et al. 2010).

As a nation, our overall walking and bicycling rates lag behind many other countries, both developed and developing (Kohl et al. 2012 cited in Hirsch et al. 2014b). Ireland, France, Great Britain, Norway, Denmark, Finland, Germany, Sweden, Spain, the Netherlands, and Switzerland each have higher shares of walking and bicycling trips than the United States (Pucher et al. 2010, cited in Hirsch et al. 2014b). Due to sprawling development patterns, American trips tend to be of longer distance than those in other countries, and this difference may be a primary reason for Americans' low rates of walking and bicycling. However, at least half of all American trips are within biking distance (shorter than two or three miles) and almost a third are less than one mile, which is walkable by most people (Pucher and Dijkstra 2000). The authors attribute the use of the car for these short trips to the low cost (relative to Europe) of owning a car, the lack of bicycling and walking infrastructure, and the car-oriented culture in America. Even Canadians bicycle to work at three times the rate of Americans (Pucher and Buehler 2006). A statistical analysis revealed that this difference could be partially explained by shorter average trip distances (due to denser, more mixed-use development) and lower bicyclist fatalities in Canada. While more than two-thirds of American bicycling trips are for recreation rather than transportation, this statistic is almost flipped for the Netherlands and Germany, where transportation accounts for about 60% of all bicycling trips (Pucher and Dijkstra 2000).

Rates of walking and bicycling among older adults in America are lower than that of America as a whole (US DOT 2010), while there is less of an age discrepancy in other countries. In Germany, 50-55% of all older adult trips are made by foot or bicycle (Pucher and Dijkstra 2000, 2003). While 10% of trips made by 18-24 year old Germans are on bicycle, the statistic drops only slightly to 7% for those over 75. Among Germans,

the share of trips completed through walking increases (from 17% to 48%) from the 18-44 year old age group to the older adult age group, yet in the U.S., walking declines slightly among the older adult age group. While bicycling trips account for 23% of all transportation trips taken by older adults in the Netherlands, 15% in Denmark and 9% in Germany, the older adult transportation bicycling rate in America is only 1% (Buehler and Pucher 2012). The results from a 2008 survey of older Americans suggest that older adult walking and bicycling rates may increase if America adopted more walkable and bikeable street design: more than half of older adults reported that they would walk or bicycle more if the streets were safer for these uses (Lynott and Figueiredo 2009).

Despite the larger trend towards physical inactivity and against active transportation among older adults in America, walking, both for transportation and recreation, has some popularity among older adults. Walking, after driving, is the second most prevalent form of transportation among older adults; 8.8% of all older adult trips are pedestrian, as compared to 2.2 % completed through public transportation and 0.2% through taxi (NTHS 2000, cited in Farber et al. 2011). Walking is also the most common form of physical activity, whether for transportation or recreation, among older adults (CDC 2014, citing Hoehner 2005). These trends are not surprising, given that walking may be one of the physically easiest and least expensive forms of physical activity.

Walking, Bicycling, Physical Activity, and Health

Walking and bicycling, as forms of physical activity, are associated with improved health outcomes for older adults. The Centers for Disease Control (CDC 2014, citing CDC 2011) state that regular physical activity is of paramount importance for older adults, and recommend that older adults get at least 150 minutes per week of moderate intensity aerobic activity, such as brisk walking. While some researchers have looked specifically at older adult walking and/or bicycling (Huy et al. 2008), the majority of

studies explore physical activity more broadly among older adults. For older adults, physical activity is associated with a number of improved health outcomes, including physical health (Huy et al 2008), mental health (Lindwall, Larsman, and Hagger 2011; Whitaker 2005), cognitive ability (Angevaren et al 2008) and decreased risk of Alzheimer's disease (Scarmeas 2009). Physical activity can decrease depression; it can also help older adults with Type 2 diabetes manage blood sugar and reduce risk of heart disease and stroke (Massachusetts Healthy Aging Collaborative 2014). Physical activity is especially important as a preventative factor against falls, which are common in older adults. Annually, a third of the older adult population experiences a fall resulting in injury, which in turn increases the risk of early death (CDC 2014). While many older adults, especially those who have already suffered a hard fall, decrease their physical activity because of fear of experiencing another fall, reducing physical activity is actually counter-productive, because it leads to reduced physical fitness which may increase the risk of falling (CDC 2014 citing Vellas et al. 1997).

Several studies of the general population, though not specifically about older adults, also suggest the health benefits of walking, bicycling, and active transportation. Walking and bicycling are associated with lower risk of breast cancer (Luoto et al. 2008, cited in APHA 2010a). Among the general population, walking and bicycling for commuting has been linked to an 11 % reduction in cardiovascular risk (Hamer and Chida 2007) and lower percentages of obesity and diabetes (Pucher et al. 2010). A case study of the Portland, Oregon metro region estimated that increased walkability, through street connectivity, retail employment density, total employment density, population density and proximity to the central business district, would translate into reductions in coronary heart disease deaths and overall mortality, and therefore save money in health care spending (APHA 2010b).

The Built Environment Can Help or Hinder Walking and Bicycling

Consistent with the healthy aging model's stance that healthy aging is a product of both individual and community factors, the physical characteristics of a community's built environment can encourage or discourage walking and bicycling among older adults. One's ability to choose to walk or bicycle is at least somewhat dependent on the "walkability" or "bikeability" of the surrounding neighborhood. Several development patterns are generally agreed to contribute to walkability and bikeability: compact development, mixed use development, street connectivity, and street design elements such as sidewalks, crosswalks, bike lanes, off-street pedestrian or bike paths, lighting, shade trees, benches, and human scale design (EPA 2013).

Walkability is measured subjectively, by asking respondents to rate the walkability of an area, or objectively, through use of mapping software such as GIS. One of the most popular and readily available measures of walkability is the Walk Score®. Walk Score® is a freely available scoring system that measures walkability primarily as a function of walking distance to destinations, intersection density, and block length (Walk Score® 2015a). Walk Score® has been shown in some cases to be significantly positively correlated with several objective and subjective measures of walkability (Carr et al. 2009, 2010; Duncan et al. 2011). By contrast, a small pilot survey among adults over the age of 70 found no relationship between Walk Score® and walking or bicycling (Takahashi et al. 2012).

A number of studies have found links between living in a walkable or bikeable built environment and increased likelihood of walking or bicycling. Most of these studies looked at the all-ages population. In both low and high income neighborhoods of King County Washington and Baltimore, living in a high walkability neighborhood was associated with a higher percentage of walking to work (Frank et al. 2009). Additionally, the same study found a statistically significant positive relationship between self-reported

walk trips (for all purposes) per day and increased walkability of the neighborhood in King County, WA. The highest walkability neighborhoods had 6.45 times the number of walking trips and 52% fewer household vehicle miles travelled than the lowest walkability neighborhoods.

Perceived safety of bicycling infrastructure and short distance to destinations were associated with increased bicycling in a study of six U.S. cities (Xing et al. 2010). Having a greater number of destinations within 400 meters of one's home was associated with walking or bicycling for transportation in a study of adults living in urban areas (Hoehner et al. 2005). Some studies have linked low walkability neighborhoods directly to obesity and diseases related to obesity. For instance, a study of the Phoenix area found that, even after controlling for demographic and socio-economic characteristics, higher walkability neighborhoods were associated with lower likelihoods of being in a "high disease cluster" of obesity, lipoid metabolic disorder, diabetes, hypertension, and heart disease (Lathey et al. 2009).

Links between the built environment and the prevalence of walking and bicycling by older adults, specifically, has been the focus of a smaller number of studies. Unfortunately, many older adults, like the general population, live in environments unsafe for pedestrians and bicyclists. In a poll by the AARP, 40% reported living in neighborhoods with inadequate sidewalks, half of those people surveyed had no safe pedestrian crossings on main roads close to their homes, and 55% had no access to bike lanes or paths (Lynott 2009). One study found that higher Walk Score® was associated with more minutes per week of transport walking among a sample of late middle-age and older adults from several cities across the U.S. (Hirsch et al. 2013b). Greater distance to and lower density of "pedestrian oriented uses" such as nightlife were associated with lower odds of meeting physical activity recommendations among a multi-ethnic sample of 45 to 84 year-old New Yorkers (Hirsch et al. 2013a). Women aged 40 years and older

who lived in rural, and presumably less walkable, areas were more sedentary than their urban counterparts in a nationally representative study of American women's leisure time physical activity (Wilcox et al. 2000). Older men who lived near parks and trails in high socio-economic status (SES) neighborhoods in Portland, OR, were more likely to maintain or increase walking in a period of two years, but this trend was not significant for men living in low-SES neighborhoods (Michael et al. 2009). Another study of adults 50-75 years old, also in Portland, found that mixed-use land use patterns were positively associated with neighborhood walking, walking for transportation, walking for household errands, and meeting physical activity recommendations (Li et al. 2008). Furthermore, this study found that a 10% increase in land use mix was associated with a 25% reduction in the prevalence of overweight/obesity, presumably because increased land use mix encourages walking.

Street connectivity, density of public transit stops, and availability of green and open spaces were also positively associated with both walking and meeting physical activity recommendations. Results from an earlier study, also of older adults in Portland, indicated that, at the neighborhood level, there was a positive relationship between walking activity and several built environment components, including density of places of employment and housing, green and recreational spaces, and number of street intersections (Li et al. 2005). The same study also found a positive relationship between walking behavior and residents' perceptions of walking safety and density of parks in the neighborhood. The link between neighborhood environment and physical activity in older adults has also been affirmed among more community-oriented studies in Massachusetts cities. For example, a recent study of "aging-in-place" in Cambridge, MA, stakeholders expressed opinions that Cambridge, because of its walkability and good multi-modal access to needs and amenities, is more conducive to healthy and socially connected aging than less walkable communities (Kokinda 2014).

However, a notable limitation of most of the above cited studies is their cross-sectional nature, which does not allow for the support of a causal link. Self-selection bias detracts from these studies: residents of walkable neighborhoods may have sought out living in that particular neighborhood at least in part because they enjoy walking. At least one study has attempted to correct for this bias, and found promising results: people who moved from a low Walk Score® to a high Walk Score® neighborhood tended to exhibit greater levels of transport walking and decreased BMI after the move, yet there were no significant differences in leisure walking pre and post move (Hirsch et al. 2014b). Authors of this study suggested that the lack of a significant relationship between leisure time walking and Walk Score® may reflect that Walk Score®, because it focuses on access to destinations rather than on aesthetics, availability of walking trails, or amount of street traffic, may be more suited to measuring transportation walking rather than leisure time walking. A longitudinal study of older adults in six U.S. cities over a nine year time frame found that when the built environment changed to have more walking destinations, higher population density, and lower residential land use, residents tended to have slight but statistically significant decreases in body mass index (BMI) and waist circumference (Hirsch et al. 2014a). Changing a neighborhood's built environment to support walkability, such as building and repairing sidewalks, was found to be significantly related to walking in a study of older adult women in a sample from across the U.S. (Wilcox et al. 2000). A study of Australians found that non-cyclists who moved to neighborhoods with higher residential density and better self-reported access to parks and recreational destinations were more likely to start bicycling for transportation; non-cyclists moving to areas with more street connectivity were more likely to begin recreational bicycling (Beenackers et al. 2012).

Older adults may require higher standards of walkability and bikeability than the general population. The idea of "age-friendly cities and communities" is gaining traction

worldwide (WHO 2007). Older adult walkability, mobility, and access to multi-modal transport are key elements of what makes a city or community "age-friendly" (Fitzgerald and Caro 2014). The AARP, CDC, and numerous local organizations support complete streets and age-friendly active transportation infrastructure (Lynott 2009; CDC 2014; Transportation Alternatives 2003; Kokinda 2014; MVPC 2009). Massachusetts' state-wide complete streets law, however, makes no mention of older adults or people with disabilities (Lynott et al. 2009).

The AARP links complete streets and walkable streets with their larger effort to support "aging in place." Aging in place is the preferred lifestyle for a majority – perhaps 90% – of older Americans (Keenan 2010). Aging in place is "the ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level" (CDC 2010 cited in Lynott and Figueiredo 2011). Auto-oriented land use and limited access to transportation are barriers to aging in place: older adults living in these communities who lose the ability to drive may be unable to access the services they need. Therefore, they may need to move away from their homes to an institutional setting with in-house services.

The AARP also recommends fundamental changes in planning practice: rather than separating transportation and land use planning, the two should be integrated (Lynott et al. 2009; Lynott and Figueiredo 2011). This integration is more conducive to creating walkable, public transit accessible, mixed-use communities featuring transit oriented development (TOD). The AARP's advocacy on behalf of older pedestrians has been thorough: the organization has inventoried and conducted a detailed evaluation of both existing complete streets policies and the Federal Highway Administration's "Highway Design Handbook for Older Drivers and Pedestrians" to better support the needs of older pedestrians (Lynott et al. 2009). The CDC (2014, 43) also supports smart growth in order

to develop walkable communities that offer “safe, affordable, and convenient choices” for housing and transportation for all ages, incomes, and abilities.

Certain neighborhood scale streetscape design features are recommended to boost older adult walkability (Lynott et al. 2009; WHO 2007; Transportation Alternatives 2003, 2006). For example, sidewalks should be wide, with level pavement free from debris, and have clearly visible colored markings. Pedestrian routes should be lit by pedestrian scale streetlights. Transitions from the sidewalk to the street and at intersections should be smooth and include curb cuts/ ramps that are safe for wheelchairs. Easily visible, lighted, “count-down” pedestrian signals are the safest for older pedestrians. Transportation Alternatives (2006) further recommends that signals be timed to 2.5 feet per second, and to give five to seven seconds of exclusive crossing time, or “leading pedestrian interval” (LPI) before vehicles are allowed to turn. Wide streets should have medians with refuges so that easily tired people can catch their breath. Benches and comfortable places to sit are also important elements of popular older adult walking routes. Shade trees can improve the aesthetics of sidewalks, as well as providing a barrier between pedestrians and cars. In areas where drivers and older pedestrians are likely to interact, traffic calming measures should be used to reduce the vehicle speed. These measures can include narrowing streets, installing speed bumps, raised intersections or crosswalks, curb extensions or bus bulbs with bollards, bicycling lanes, mini roundabouts, and diagonal parking (Transportation Alternatives 2006). Off-road pedestrian and bicycle paths are also recommended for the benefit of older walkers and bicyclists (WHO 2007).

Gaps in the Literature

While there is scholarly evidence to suggest that walking and bicycling can contribute to healthy aging, and advocates, both national and local, have been working on

this issue for several years, there are no publicly available estimates of walking and bicycling among Massachusetts older adults. The Massachusetts Healthy Aging Report analyzed Behavioral Risk Factor Surveillance System data on overall physical activity rates for older adults in Massachusetts, but their report did not track data specific to walking and bicycling (Massachusetts Healthy Aging Report 2014). The American Community Survey (ACS) data for Massachusetts provides rates of transportation walking and bicycling, but only for the commuting trips of the workforce. The ACS data on active transportation therefore largely exclude the older population. Furthermore, the Massachusetts Travel Survey (MTS 2010-11) estimates active transportation, as well as recreational bicycling, across the state, but the published analyses do not explore any age-based differences. There is a need for research that characterizes active transportation and recreational bicycling among older adults in Massachusetts.

Chapter 3: Methods

Overview and Rationale

In the context of a "graying" Massachusetts, how can we help our growing older adult population stay healthy? While walking and bicycling are linked to healthy aging, there is little research on these behaviors among older adults in Massachusetts. To address this gap, my research focuses on older adult walking and bicycling in Massachusetts. These analyses could contribute to both public health and neighborhood planning initiatives by characterizing "healthy aging" behaviors in this population and developing a framework useful to future researchers wishing to track trends over time.

To summarize, the primary method of analysis for this thesis is quantitative, but I also include GIS mapping. Descriptive maps illustrate spatial patterns in the distribution of older adults in the state. Through a statistical analysis using STATA software of the Massachusetts Travel Survey 2010-2011 (MTS), I compare trip rate and mode share across different age groups: between adults age 65 and over ("older adults") and adults younger than 65 ("younger adults"), and among age cohorts (65-67; 68-72; 73-77; 79-98+) within the older adult population. I also look at whether there is a difference in rates of recreational and transportation bicycling between younger and older adults. Finally, I explore whether there is a relationship, for both younger and older adults, between living in a walkable neighborhood and engaging in more walking for transportation.

Objective 1: Descriptive Mapping

The purpose of these descriptive maps is to establish the geographic and demographic context for my quantitative analyses of older adult walking and bicycling in Massachusetts. The first two maps illustrate which regions of the state currently have higher numbers of older adults and where older adults make up a higher proportion of the population. Both of these maps display census tract level data, although town outlines are

included for geographic orientation. A third map shows projected increases in the older adult population in the coming years by town. The final two maps look, by census tract, at more specialized populations of older adults: those living alone in their own households and those living in institutional facilities, such as long-term care facilities. Older adults living alone interest me because this population may be more reliant on traveling outside of the house in order to be socially connected. Older adults living alone who also lack reliable or convenient transportation may be more at risk for social isolation. I am interested in exploring the spatial distribution of older adults living in institutional facilities who require a more constant level of care, as they may be less likely to transport themselves, but at the same time may be better able to satisfy needs to socialize and eat within their own communities.

The maps all use data from MassGIS. Below, Table 1 lists the other data sources. Data sources are also noted in fine print on each map.

Table 1: Additional spatial data sources

Maps	**Additional Data Sources**
1) Percent of entire population that is over 65 2) Count of people over 65	U. S. Census Bureau 2011: Decennial Census 2010, SF1, table QTP1
3) Population Projections: Percent Change in Older Adult Population 2000 – 2020	Executive Office of Elder Affairs (EOEA) 2013a
4) Older Adults Living Alone 5) Older Adults Living in Institutional Facilities	U.S. Census Bureau 2011: Decennial Census, 2010, SF1, table P34 MassGIS 2007: "Long Term Care Residences" layer, which includes locations of nursing homes, rest homes, and assisted living facilities
6) Walk Score® by ZIP code	Walk Score® 2015 U.S. Census Bureau 2013: ZIP Code tabulation areas

The 2010-2011 Massachusetts Travel Survey

The bulk of my research (Objectives 2, 3, and 4) explores age-based trends in transportation behavior using data from the 2010-2011 Massachusetts Travel Survey. The MTS survey is a statewide multi-modal household travel survey overseen by the Massachusetts Department of Transportation (MassDOT) and the 13 Metropolitan Planning Organizations (MPOs) of Massachusetts (MassDOT 2010). Data include trip information, based on a 24 hour travel diary kept by respondents, and individual demographic characteristics. The sample size is 15,033 households and 37,023 individuals. The survey used a stratified sampling approach whereby the survey population was divided into groups, defined by the geographic boundaries of the MPO, and a random sample was drawn from each MPO. Data tracked by the survey include the number and modes of trips taken by each respondent and whether the respondent had engaged in recreational or transportation bicycling during the study period. Demographic data include age, race, gender and income. Geographic data include ZIP code of respondent's residence.

MassDOT staff approved my request to use the MTS data in my research, and provided a link to a Microsoft Access database. I use queries to bring the variables needed for my analyses into STATA, via Microsoft Excel. While the original MTS data analysis applied weights to correct for non-response bias, I use the unweighted data to explore trends across age categories. Future analyses might explore the impact of non-response bias on demographic trends in these data; however, such analyses are outside the scope of this thesis.

A significant proportion – almost 14% – of the survey respondents were age 65 or older, but the published results of the survey do not look at how mode share – or any of the other results – vary by age (MassDOT 2010). My research expands on the published MTS results by exploring age-based trends in:

- Trip Rate and Mode Share (Objective 2)
- Recreational and Transportation Bicycling (Objective 3)
- The relationship between Walk Score® and Walk Share (Objective 4)

These three main research questions share a common structure: all examine age-based trends in walking and/or bicycling by comparing the prevalence of various travel behaviors between younger (18-64) and older (65 or above) adults. The 65 year old cut-off was chosen because it is considered the traditional age of retirement, and many senior citizen benefits start at this age. Respondents who refused to report their age were eliminated from my sample, leaving me with a sample size of 27,725 people – 23,411 between 18 and 64 years of age, and 4,314 who were 65 years or above.

Objective 2 also includes a comparison of travel behavior (namely, trip rate and mode share) across four age categories (65-67; 68-72; 73-77; 78-98 plus) of older adults. The cutoff points were set to make the four categories have roughly the same number of individuals, as determined by the quartiles and median of the age distribution.

Table 2: Age Categories of older adult subsample

Age Range	**Number of Respondents**
65 - 67	1,064
68 - 72	1,180
73 - 77	991
78- 98 +	1,079

Objectives 3 and 4 look only at the two larger groups (younger/older adults) due to smaller sample sizes and incomplete data in the original dataset.

For each objective, statistical tests, including chi-square, ANOVA, t-tests, and Spearman's correlations, are chosen based on the type of data comparisons being made. These tests indicate the statistical significance of any trends observed in the descriptive statistics.

Objective 2: Age-based trends in trip rate and mode share

The rationale for this question is that exploring age-based differences in the amount of travel (trip rate) and the type of mode used (mode share) could be a preliminary step in research and advocacy for older adult active transportation. First, in order to understand active transportation within the overall transportation context, I look at whether the total amount of travel outside of the home varied based on age. To answer this question, I compare the average number of trips taken (or trip rate) across age groups. My hypotheses are that:

1) Older adults (65 plus) will take fewer trips outside of the home than younger adults (18-64)

2) When comparing the four age-based cohorts of older adults (65-67; 68-72; 73-77; 78-98+), trip rate will be observed to decrease with age

I test the first hypothesis using a t-test comparison of means, and the second hypothesis using ANOVA.

Then, I explore age-related trends in active transportation through comparing mode share in different age groups. Mode share is typically expressed as the percentage of a particular population that uses each available mode of transportation. It is computed based on the reported travel trips of individuals. The overall number of trips in the sample was 121,659, of which 106,268 were completed by younger adults (18–64 years old) and 15,391 were completed by older adults (65 or older). As noted in Table 3, within the older adult subset, the trip distribution was as follows.

Table 3: Number of trips by older adult age category

Age Category	Number of Trips
65 - 67	5,450
68 - 72	5,869
73 - 77	4,021
78 – 98 plus	4,365

The MTS study tracks 13 different transportation modes: walk, bike, auto/van/truck driver, auto/van/truck passenger, public bus, train, ferry/boat, dial-a-ride/paratransit, school bus, taxi, motorcycle driver, motorcycle passenger, and other. In order to better focus on my primary mode of interest, active transportation, I collapse some of the less used non-active transportation modes. A number of the modes, specifically ferry/boat, paratransit, school bus, taxi, motorcycle driver/passenger, and other, are used less than one percent of the time for the adult sample. I collapse all of these modes, with the exception of paratransit, into the "other" category. I continue to use paratransit as a separate category, despite its small representation in the overall adult population, because paratransit services were identified as an important resource for older adults by the Commonwealth's Department of Elder Affairs in their state-wide older adult services planning process (EOEA 2013a). Finally, because the bus and train modes also have a fairly small prevalence (accounting for about 4% of trips each), I collapse them into one "public transit" category. After folding these modes together, my dataset tracks seven modes: walk, bike, auto/van/truck driver, auto/van/truck passenger, public transit, paratransit, and other (including motorcycle, ferry/boat, school bus, taxi, and other modes).

I expand on the publicly available MTS mode share calculations by computing this simplified mode share for the younger adult group, the older adult group, and the four age categories within the older adult sub-sample. These "side-by-side" mode share calculations give a preliminary indication of whether age plays a role in the transportation modes of Massachusetts adults. My hypotheses are that:

1 a) Younger adults will have a higher share of active transportation (walking and bicycling) than older adults

b) Younger adults will have a lower share of being a passenger or using paratransit than older adults

2 a) Within the sub-sample of older adults, younger age-cohorts will have higher shares of active transportation than older age-cohorts

b) Again with this sub-sample, younger age-cohorts will have lower shares of being a passenger or using paratransit

I created tables of mode share by age group, and used a chi-square test to test these hypotheses.

Objective 3: Age-based trends in recreational/transportation bicycling

I compare the prevalence of recreational and transportation bicycling between the younger and older adult groups. The MTS data include information on bicycling, both for recreation and transportation. Respondents were asked how many days in the past week they went on a recreational bike ride, and on how many days they had ridden a bicycle for transportation. A high majority of respondents did not bicycle at all, so I collapse these categories into a single dichotomous variable (bicycling / no bicycling).

After removing observations with missing or refused recreational biking variables, my sample size is 17,704 adults. Of these, 16,216 are younger adults and 1,488 are older adults. I follow the same process for transportation bicycling. This time, after removing the observations with no data or refusals for the transportation bicycling variable (total of 10,063 observations deleted), I have a sample size of 17,662. Of these, 16,177 are younger adults, and 1,485 are older adults.

My hypothesis is that, similar to the findings of Xing, Handy, and Mokhtarian (2010), older adults will have higher rates of recreational bicycling than younger adults, but there will be no significant difference in transportation bicycling between age groups. The authors of this previous study surmised that higher recreational bicycling rates among older adults were observed because this age group typically has more leisure time. I test these hypotheses with chi-square tests.

Objective 4: Age-based trends in the relationship between Walk Score® and walk share.

This question adds to research looking at how neighborhood design and walkability may relate to levels of active transportation, and whether there is a statistically detectable association between walkability and walkshare. I obtained data on the Walk Score® of each ZIP code centroid. Therefore, my Walk Score® data represent the Walk Score® of the center point of the ZIP code rather than the Walk Score® of the entire ZIP code polygon. To visualize the location of walkable and less walkable areas, I create a map illustrating Walk Score® by ZIP code. On the quantitative side, I calculate the "walk share" variable by collapsing the trip data from the MTS survey by ZIP code. This variable represents the proportion of all trips in a given ZIP code that were completed by walking. I calculate a walk share for the entire sample, as well as walk shares just for the adults under 65 and another just for adults 65 or older. Due to data limitations (sample size decreases when the data are collapsed to the ZIP code level) I do not compute separate walk share variables for the four older adult age cohorts.

I then explore the relationship between walk share and publicly available Walk Score® data by ZIP code. My hypothesis is that there will be a statistically significant positive relationship between a ZIP code's Walk Score® and its walk share for the entire adult sample, as well as for the younger adult and older adult sub-samples. I explore the statistical significance of these associations with a Spearman correlation coefficient.

Older adult pedestrians may have less physical mobility than younger pedestrians: what is "walkable" to a younger person may not be for an older person. Therefore, I further break down the correlation coefficient by age category to test the strength of association between walkability and walk share, and construct scatterplots to visually compare these relationships across age groups.

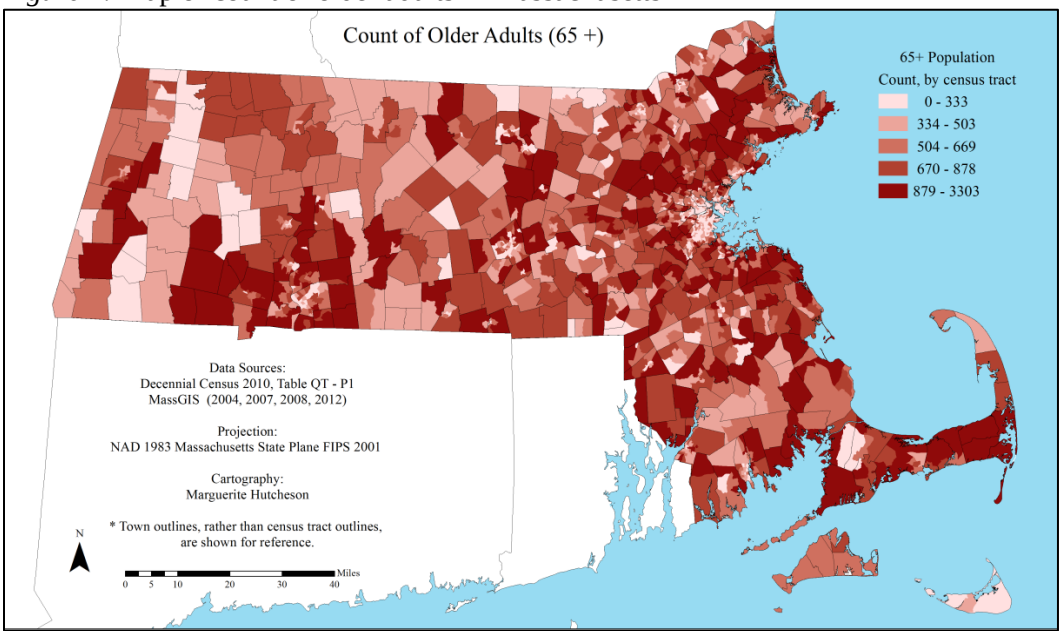
Chapter 4: Results

The goal of my research is to explore age based trends, particularly relating to older adults, in walking and bicycling in Massachusetts. In this section, I will first show the results of my descriptive mapping of older adults across the state. Then, I discuss the results of my statistical analyses of the MTS Survey data. I summarize my findings on differences in trip rate and mode share between younger and older age groups and within smaller age categories within the older adult sub-population. I also discuss how prevalence of bicycling – both transportation and recreational – differs in younger as compared to older adults. Finally, I bring in Walk Score®, a measure of walkability, into my analysis of age-based transportation trends. I display the map of Walk Score® across the state, and I summarize the results of my analysis of the relationship between the prevalence of walking (as measured by MTS data) and walkability (as measured by Walk Score®).

Objective 1: Descriptive Mapping

The purpose of these maps is to illustrate the geographic distribution of older adults (above 65) in Massachusetts. Figure 1, depicting the count of all adults over 65 by census tract, does not seem to indicate a strong spatial pattern. Census tracts are designed to have similar population sizes, so this lack of pattern is not unexpected.

Figure 1: Map of count of older adults in Massachusetts



In Figure 2, however, which depicts a percent (the count of older adults over the total population), a clearer pattern emerges: the farther flung and more rural areas of the state (particularly Cape Cod and Western Massachusetts) have higher percentages of older adults, while the urban core areas, particularly Boston, appear to have lower percentages of older adults. The “ring suburbs” around Boston, however, have higher percentages of older adults.

Figure 2: Map of percent of older adults in Massachusetts

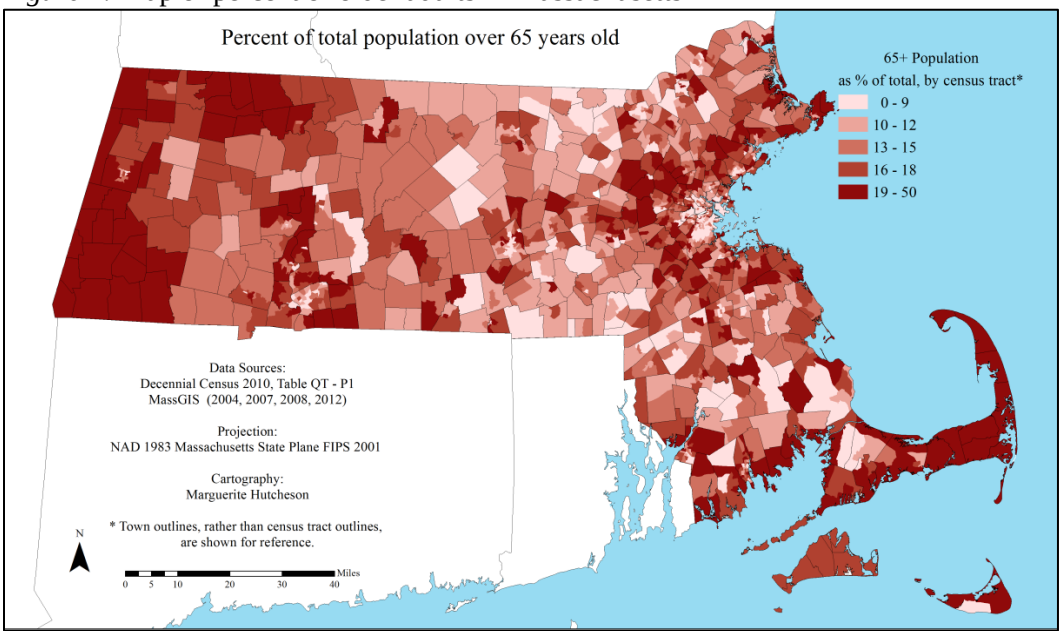


Figure 3 maps projections available from the Executive Office of Elder Affairs. Areas with the largest percent increase in the number of older adults tend to be rural areas, such as Central and Western Massachusetts. Boston and the denser inner core suburbs have the lowest projected increases in the number of older adults.

Figure 3: Map of projected increase in older adult population from 2000 to 2020

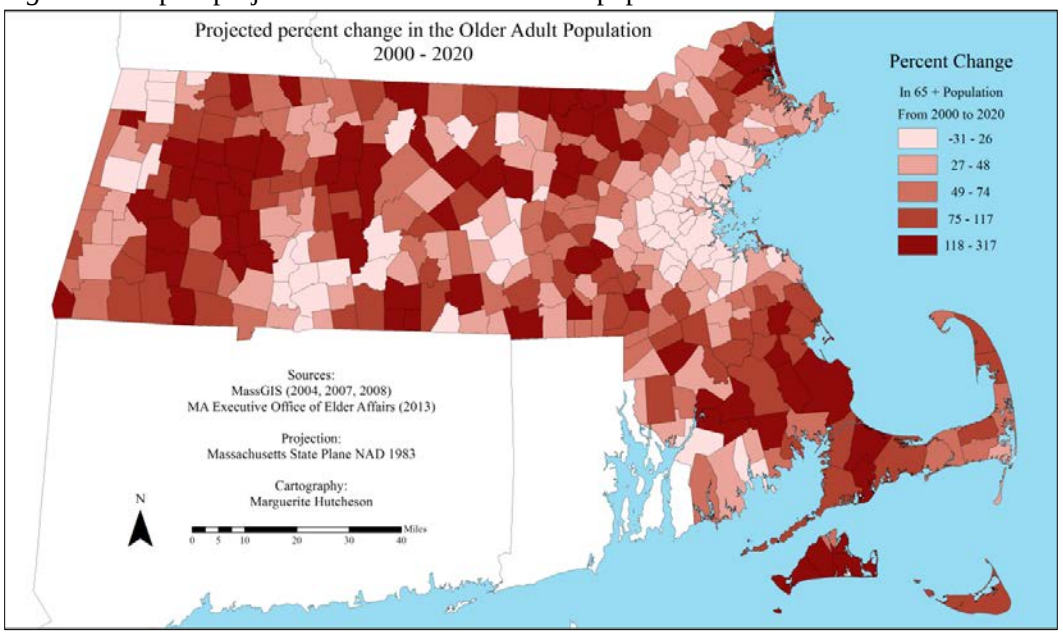
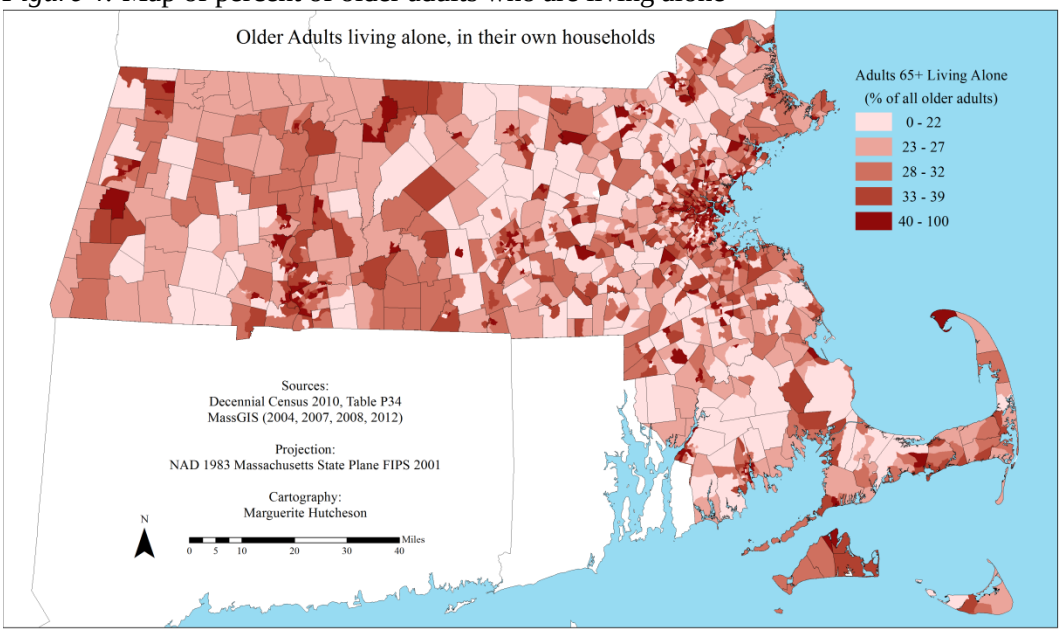


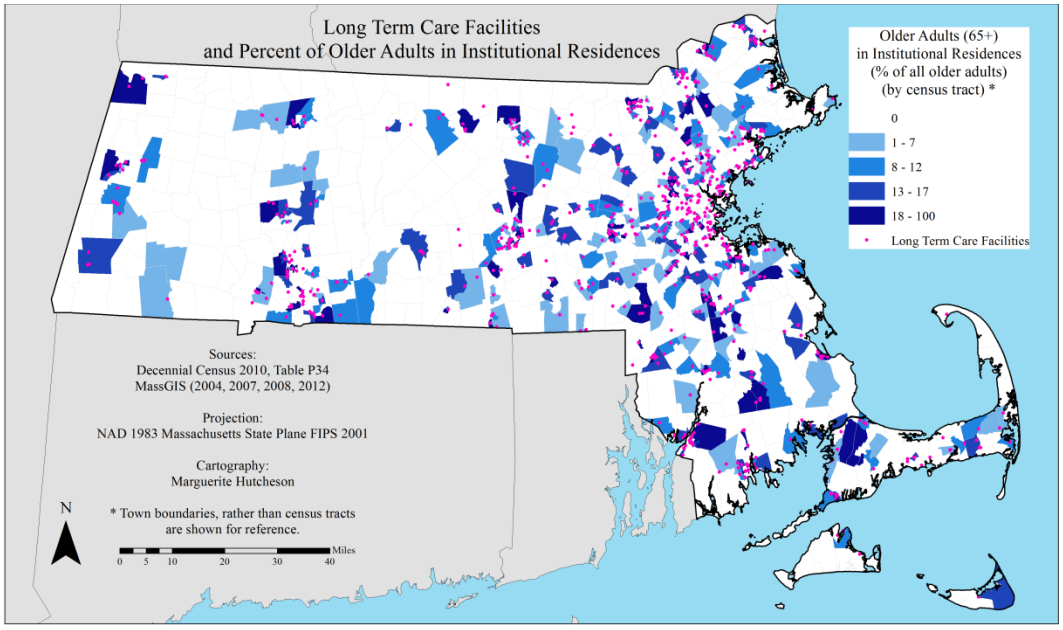
Figure 4 does not have a strongly discernible pattern, but perhaps more urban areas of the state (Boston, Worcester, and Springfield) may have higher percentages (of the total older adult population) of older adults living alone.

Figure 4: Map of percent of older adults who are living alone



In Figure 5, there appears to be a fairly good spatial match in the locations of Long Term Care Residences and the percent of older adults who are living in institutional facilities. While there is considerable variation, facilities and older adults living in facilities appear to be more prevalent in and around more urban areas.

Figure 5: Map of percent of older adults who are institutionalized, with long-term care facilities



Objective 2: Age-based trends in trip rate and mode share

Trip Rate for Younger and Older Adults

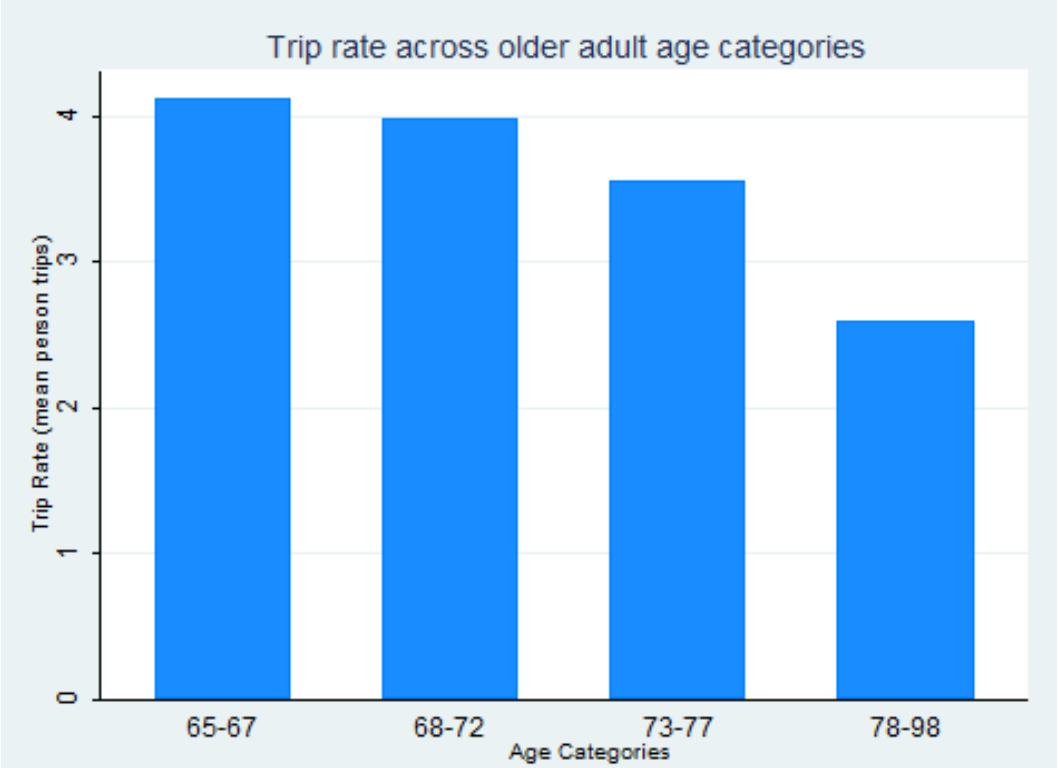
The MTS survey asked each respondent to record the number of times they traveled within a 24 hour period; this variable is called "person trips." My hypothesis was that the mean person trips (or "trip rate") would be lower among older adults, as compared to younger adults, and I tested this comparison with a t-test. The results provide support for my hypothesis: trip rates for younger adults were 4.5, compared to 3.6 for older adults, and this difference was statistically significant ($p<0.01$).

Trip Rate for the Older Adult Sub-sample

I further hypothesized that trip rate would decline across older age categories within the older adult sub-sample. As noted in Figure 6, trip rate decreased across the four old age categories. The marginal decline increases with age: though the 68-72 year old age group has a slightly lower trip rate (3.97) than the younger 65- 67 year old age

group, trip rate for the oldest group (3.55) is almost one trip less than that of the second oldest group (2.59). ANOVA analysis and post-hoc tests (Sidak, Bonferroni, and Scheffe) indicated that all differences between the four groups were statistically significant at the $p<0.01$ level.

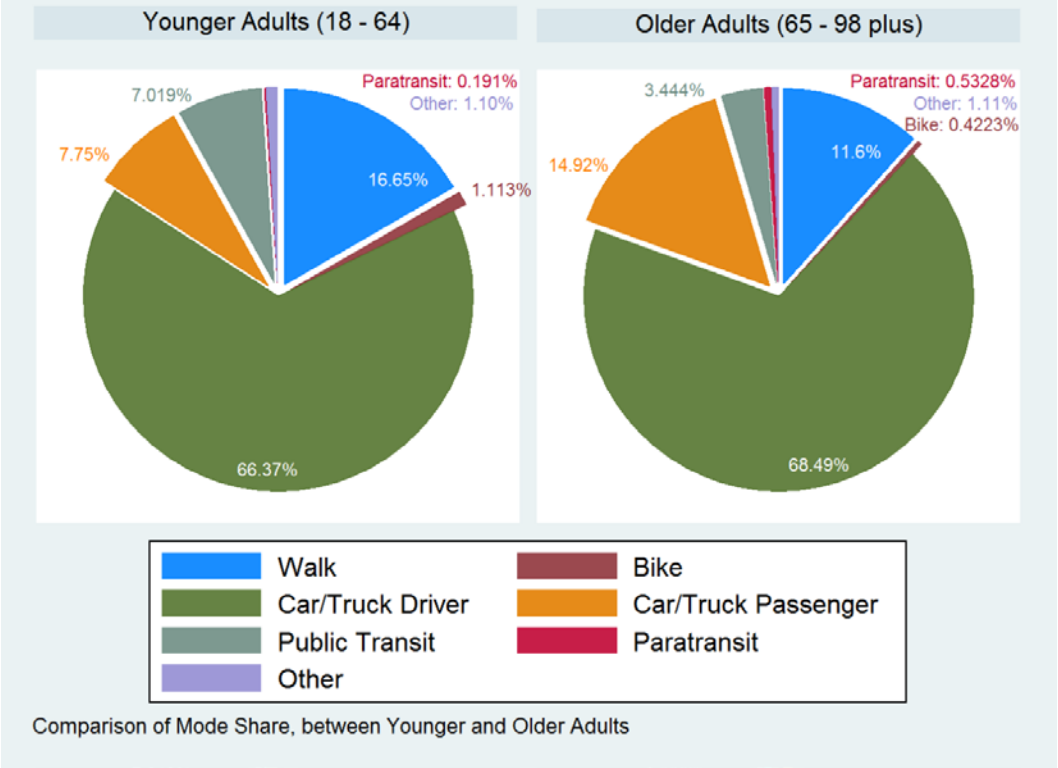
Figure 6: Trip Rate among Older Adults, by age category



Mode Share comparison between Young and Old Adults

I hypothesized that younger adults would have a higher share of both walking and bicycling than older adults, and that older adults would have a higher share of being a passenger in a car or using paratransit, as compared to younger adults. First, to look at the trends visually, I made side by side pie charts of mode share for younger or older adults, shown in Figure 7.

Figure 7: Comparison of mode share between younger and older adult



From the descriptive statistics, it appears that the older group has lower rates of walking, bicycling and taking public transit, but higher rates of being in a car, either as driver or as a passenger, and taking paratransit, as compared to the younger group. Table 4 provides a breakdown of the differences across the young and old age groups. The results of seven chi square tests, run on the dichotomous young/old variable and the seven dichotomous "dummy" mode variables (non-walking trip/walking trip, etc.), found that all differences between younger and older adults were statistically significant ($p<0.01$).

Table 4: Mode share for younger and older adults

Mode	**Younger Adult Trips** (Percentages are out of 106,268 total younger adult trips)	**Older Adult Trips** (Percentages are out of 15,391 total older adult trips)	**Trend** (* = result is significant at p<0.01)
Non-Walking Trip	83.3%	88.4%	The older adult group has a lower walk share. *
Walking Trip	16.7%	11.6%	
Non-Bicycling Trip	98.9%	99.6%	The older adult group has a lower bicycling share. *
Bicycling Trip	1.1%	0.4%	
Non-Car(Driver) Trips	33.6%	31.5%	The older adult group has a higher car driving share. *
Car (Driver) Trips	66.4%	68.5%	
Non-Car (Passenger) Trips	92.2%	85.1%	The older adult group has a higher car passenger share. *
Car (Passenger) Trips	7.8%	14.9%	
Non-Public Transit Trips	93.0%	96.6%	The older adult group has a lower public transit share. *
Public Transit Trips	7.0%	3.4%	
Non-Paratransit Trips	99.81%	99.47%	The older adult group has a higher paratransit share.*
Paratransit Trips	0.19%	0.53%	
Non-Other Trips	98.90%	98.89%	The older adult group has a higher “other share”. *
Other Trips	1.10%	1.11%	

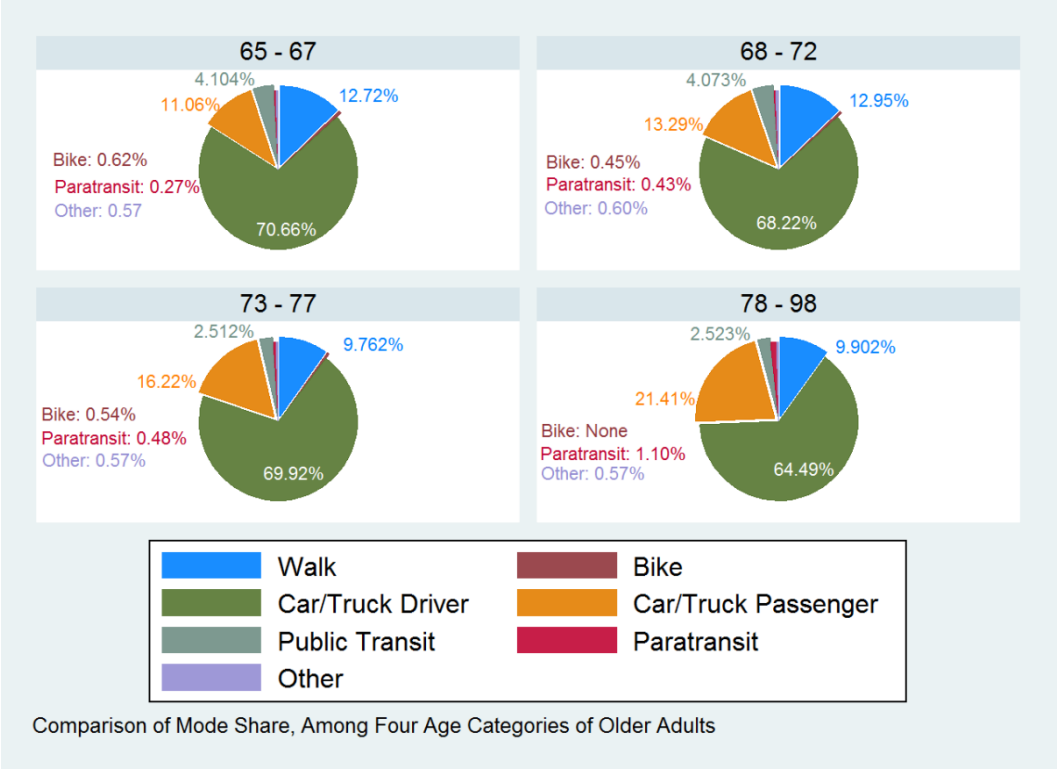
Younger adults had higher shares of active transportation (walking and bicycling) and public transportation, while older adults had higher shares of the other forms of

transportation: driving a car, being a passenger in a car, using paratransit, and using "other" forms of transportation. While all differences between younger and older adults were statistically significant, the magnitude of these differences varied. For bicycling, paratransit, and other modes, the differences between older and younger adult rates was less than 1%. These modes also accounted for a very small portion of all trips. The difference between the prevalence of car driving in older and younger adults was also small, at only a few percentage points. For both groups, though, driving a car is by far the most popular mode, accounting for about two thirds of all trips. It appears that older and younger adults may differ more in their utilization of walking, being a passenger in a car, and taking public transit. For these modes, the differences between the two groups were several percentage points.

Mode Share Older Adult Sub-sample

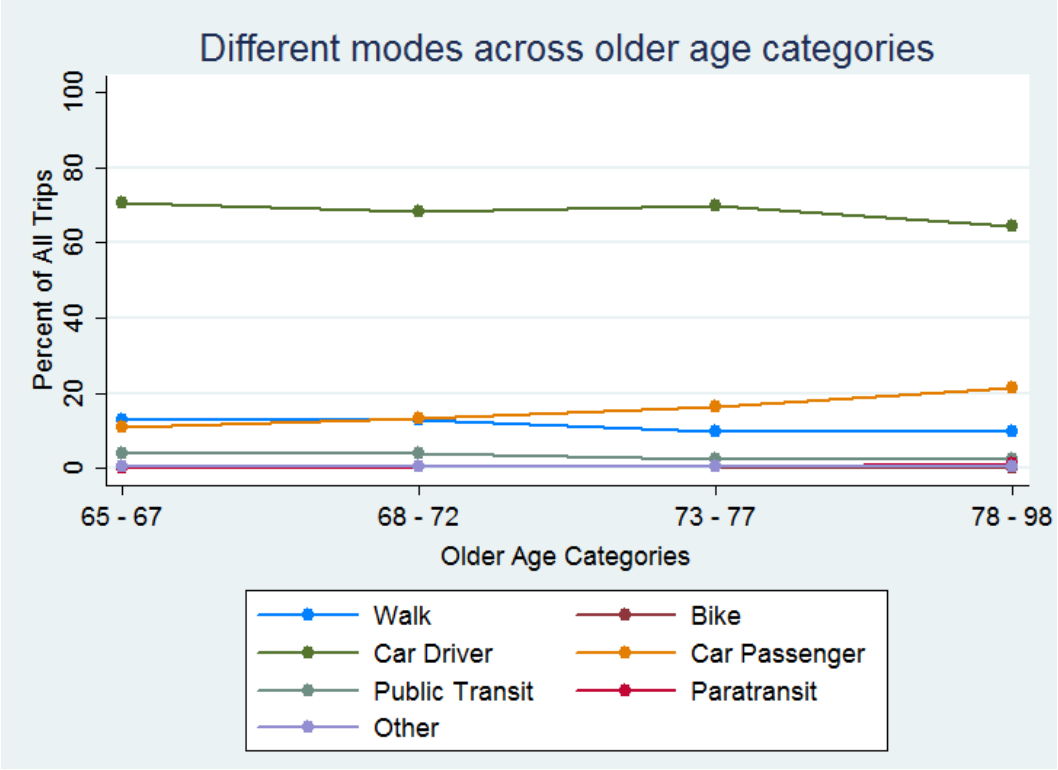
My hypotheses were that the younger age cohorts (of this older sub-sample of adults) would have higher shares of active transportation (walking and bicycling) than the older age-cohorts. Younger age cohorts would also have lower rates of being a passenger or using paratransit than older age-cohorts. Figure 8 below visualizes the mode share across age categories, and it appears that the trends go generally in the direction of my hypotheses.

Figure 8: Comparison of mode share among the four older age categories



Chi-square analyses found significant differences ($p<0.01$) for all modes (walking, bicycling, driving, car passenger, public transit, and paratransit) across all age groups. The exception mode was "Other," where no significant difference was observed across age groups. The share of trips completed by walking, bicycling, driving, and public transportation decreases significantly ($p<0.01$) from younger to older age categories. As Figures 9, 10, and 11 illustrate, however, there were slight upticks between younger and older age groups within the overall trends of decreases. These upticks, while small in magnitude, were found to be statistically significant. The share of trips completed as a car passenger or through using paratransit increases significantly with age ($p <0.01$), and showed the hypothesized consistently upward trend with age.

Figure 9: Age based trends in prevalence of different modes for older adults



As shown in Figure 9, being a car passenger increases with age, while driving decreases, overall. There is some variation in this trend, however: there is a slight uptick in driving between 68 – 72 year olds and 73 – 77 year olds.

Figure 10: Age based trends in Walking, Public Transit, and being a car passenger for older adults

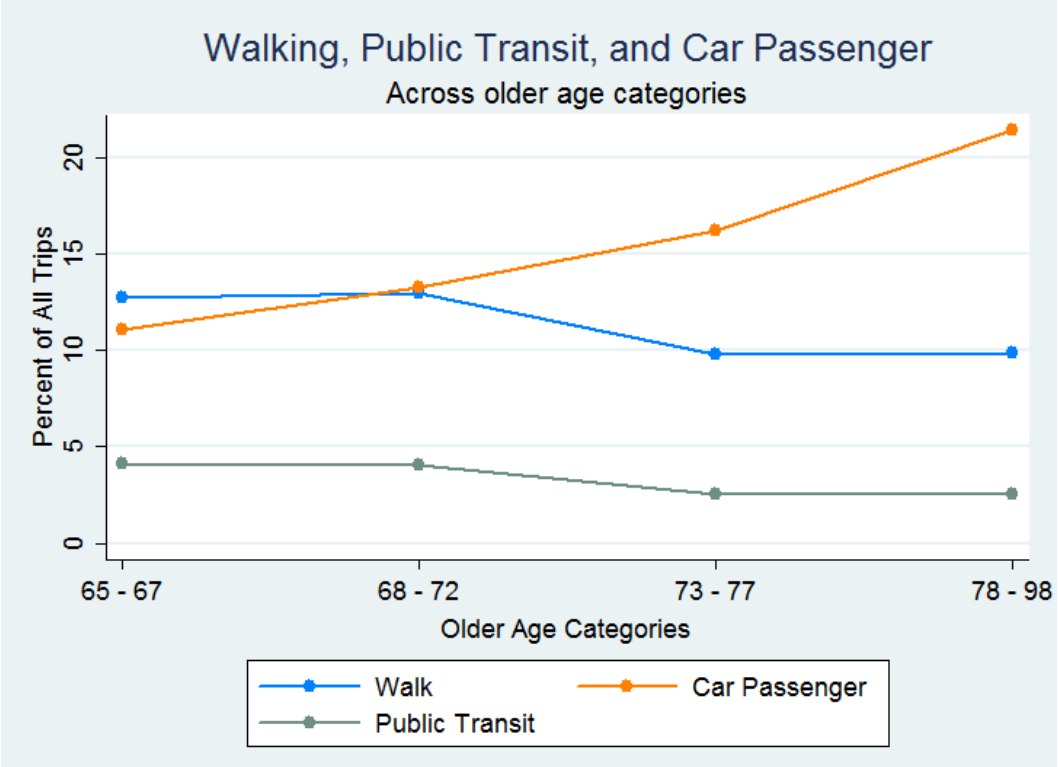
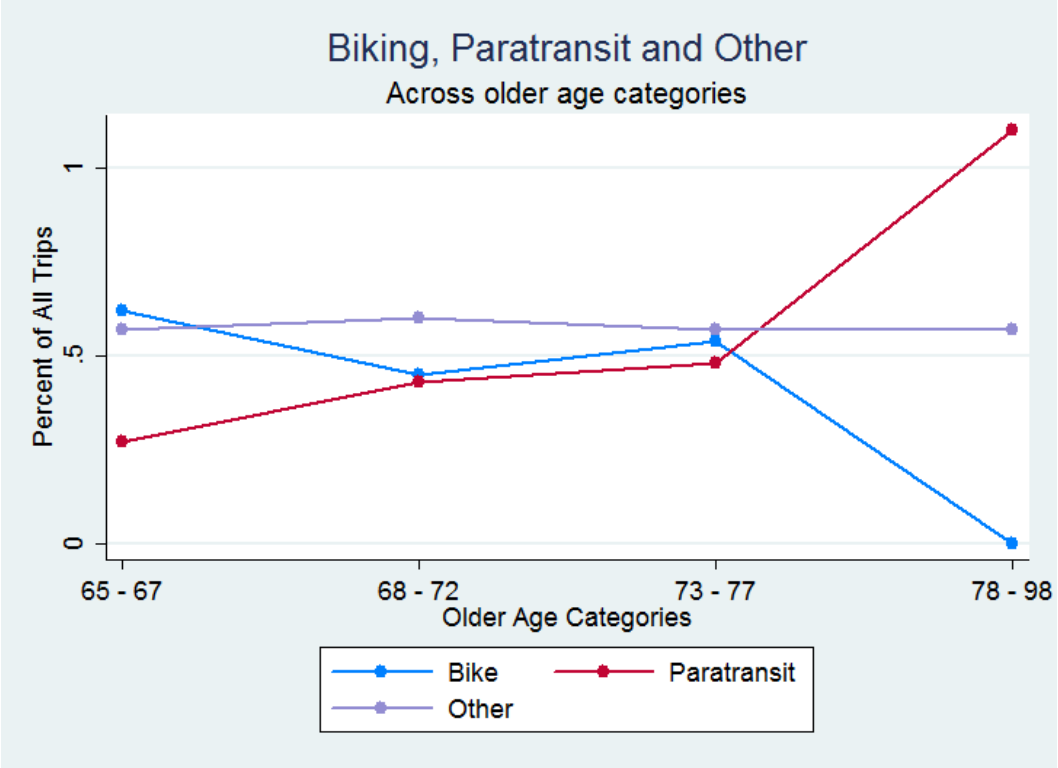


Figure 10 shows overall decreases in walking and public transit use, with increases in being a car passenger. The decrease in walking is not entirely smooth: while walking decreases between the middle two age categories and the youngest and oldest, there were slight, but statistically significant increases between the 65-67 age group and the 68-72 age group as well as between the 73-77 age group and 78-98 age group. Though there was an overall decrease in public transit with age, there was a slight uptick between 73-77 year olds and 78 - 98 year olds.

Figure 11: Age based trends in biking, paratransit, and other for older adults

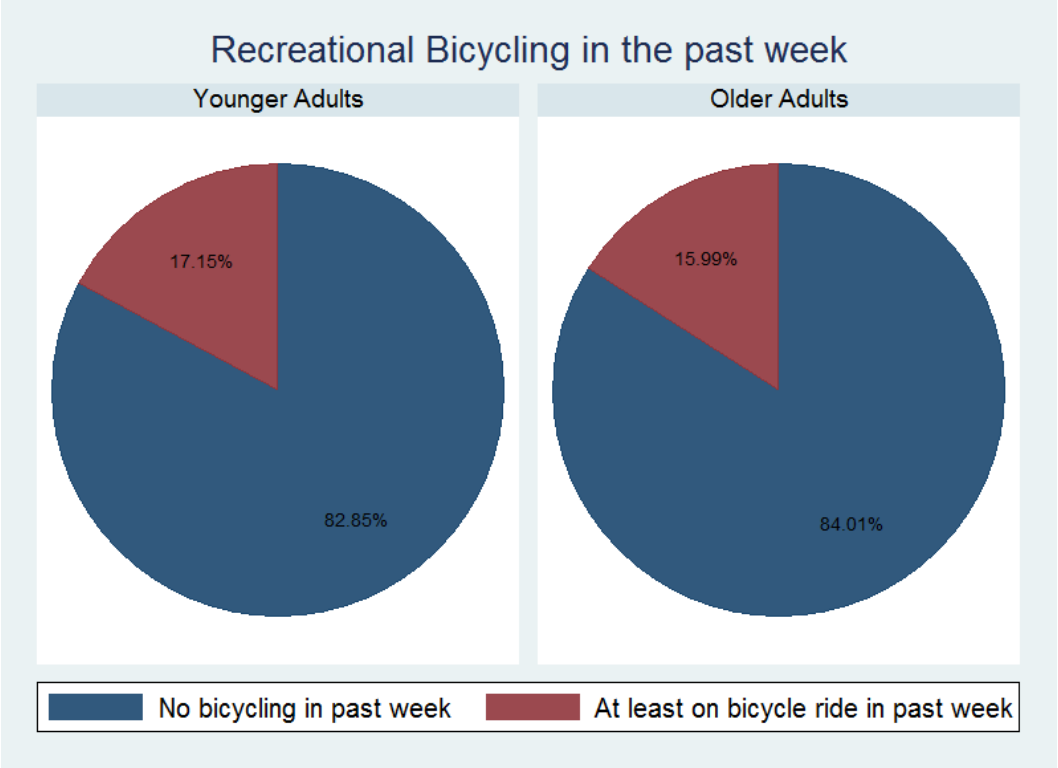


Overall, the prevalence of other modes of transportation appears flat across age groups, and there was indeed no statistically significant trend for this group of modes. Biking decreases with age and paratransit increases with age. There is some variation in the biking trend. While the younger age group (65 to 67 year olds) had the highest bike share, the third oldest age group (73 – 77 year olds) had a significantly higher bike share than their younger counterparts in the second youngest age group (68 – 72 year olds).

Objective 3: Age-based trends in recreational/transportation bicycling

My hypothesis was that older adults would have higher rates of recreational bicycling than younger adults, but there would be no significant difference in transportation bicycling between age groups. The data tell a slightly different story, with older adults having lower rates of recreational bicycling than younger adults (16.0% compared to 17.1%, respectively). Figure 12 visualizes this difference.

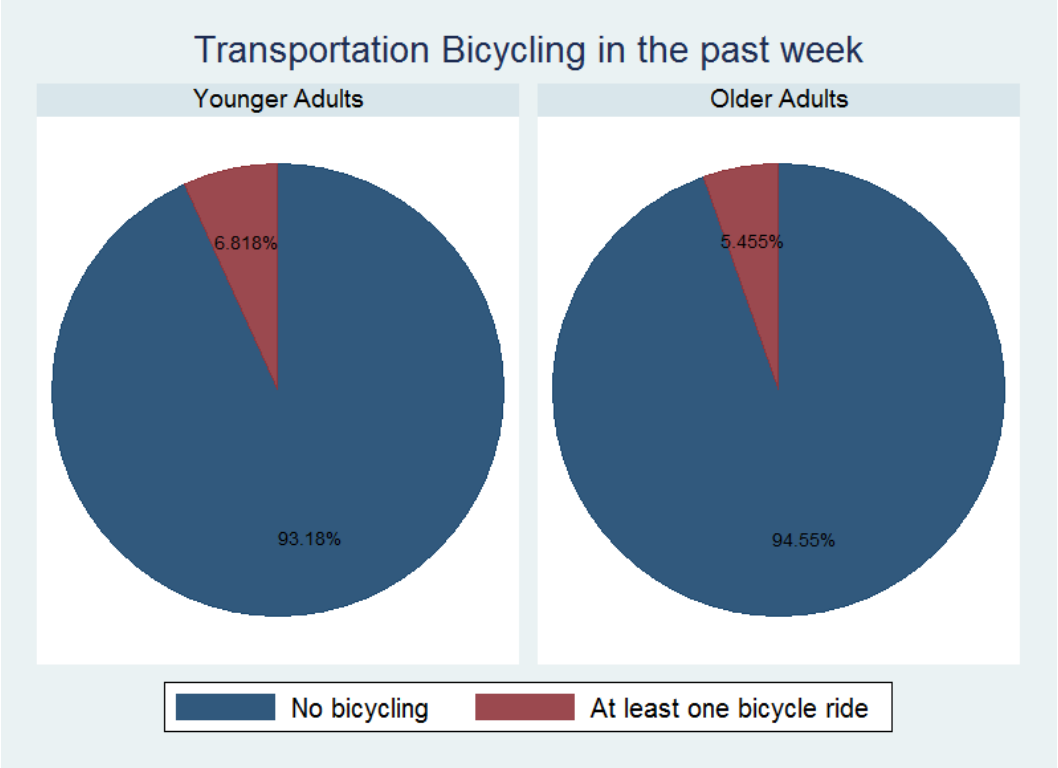
Figure 12: Age based comparison of Recreational Bicycling



However, this difference was not statistically significant.

Not surprisingly, younger adults showed higher rates of transportation bicycling compared to older adults (6.8% compared to 5.5%, respectively), as shown in Figure 13. Both age groups engage in recreational bicycling at higher rates than transportation bicycling.

Figure 13: Age based comparison of Transportation Bicycling

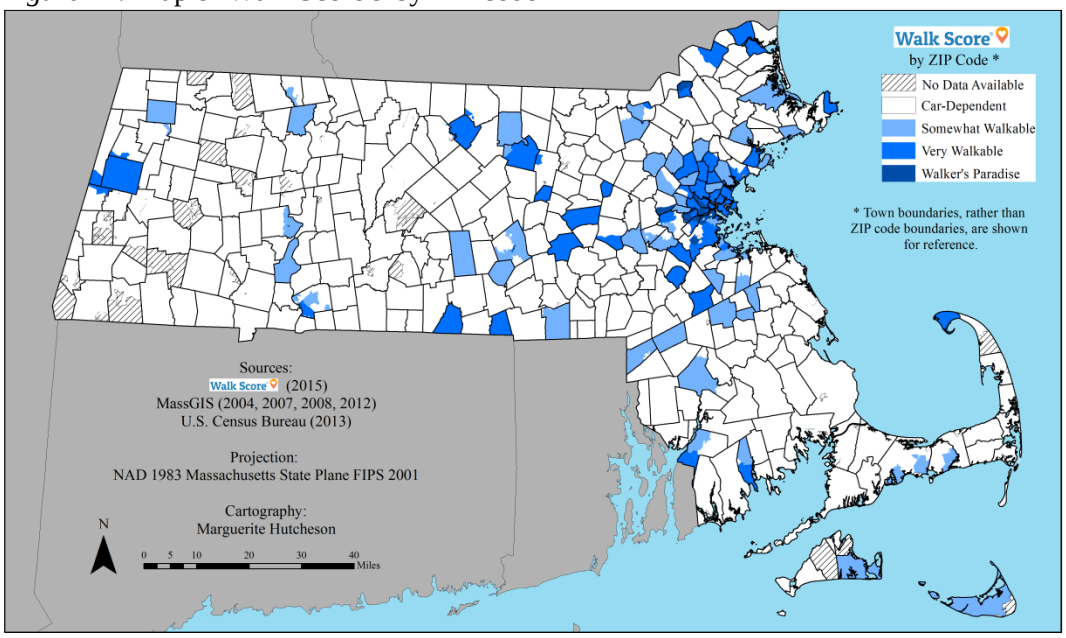


This difference was statistically significant at $p<0.05$.

Objective 4: Age-based trends in the relationship between Walk Score® and walk share.

First, I created a map, shown in Figure 14, to illustrate by ZIP code the more and less walkable areas of the state.

Figure 14: Map of Walk Score® by ZIP code



Most of the ZIP codes surveyed in the travel survey have low walkability, with a Walk Score® in the "Car Dependent" range (numeric scores 0 – 49). The ZIP codes which are on the walkability spectrum (Somewhat Walkable (50-69); Very Walkable (70-89) or Walker's Paradise (90-100) are mostly located in the Boston area, where there are also lower percentages of older adults. There are also a few isolated walkable pockets elsewhere in the state, such as Provincetown on Cape Cod.

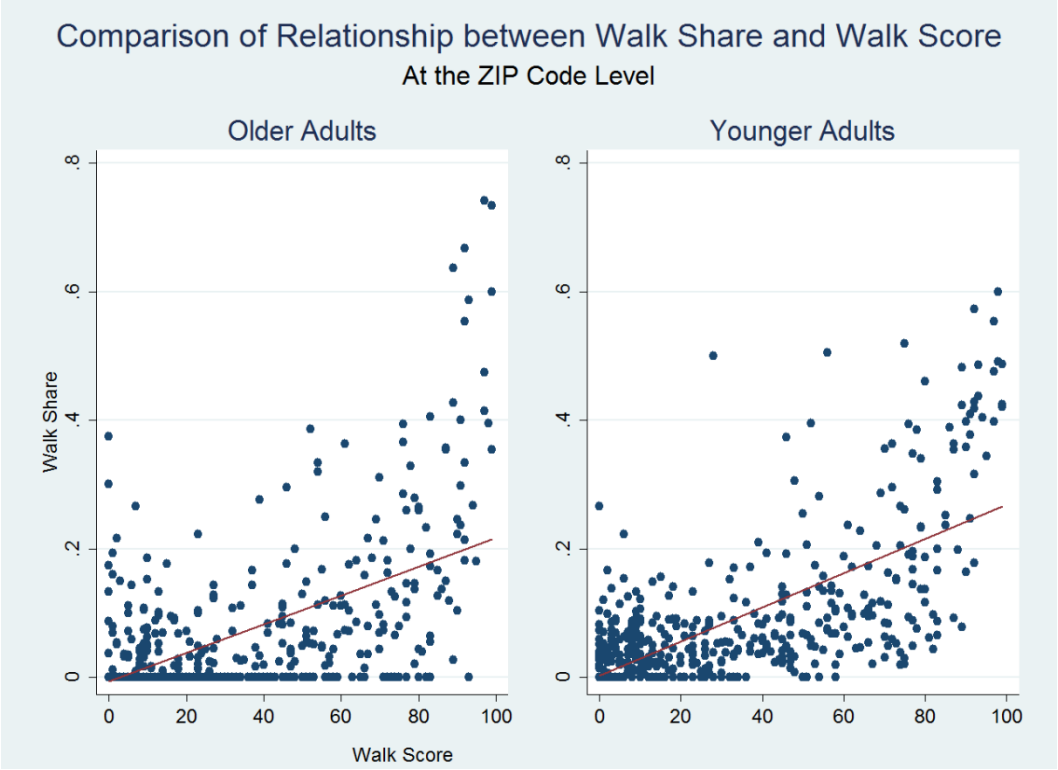
In order to estimate the number of older adults living in walkable as opposed to car dependent areas, I selected the census tracts located within at least somewhat walkable ZIP codes, and then used the census data to calculate how many older adults live in these census tracts. My result was that 216,985 older adults, or 24% of the older adults in the state live in at least somewhat walkable areas. Due to the different boundaries of ZIP code and census tract polygons, this result was only a rough estimate. My selection method likely produced an underestimation, because it counted only census tract polygons that are within or share boundaries with ZIP code polygons and did not count census tracts that have parts both inside and outside of the ZIP code polygon.

I then began the process of investigating my hypothesis that there would be a relationship between Walk Score® and share of trips completed by walking. The unit of analysis was the ZIP code. I ran Spearman's correlations to see if there was a statistically significant relationship between the Walk Score® of a ZIP code and the share of trips completed through walking by the survey respondents residing in those ZIP codes. I chose Spearman's correlations because the data were not normally distributed and the relationship between walkability and walk share could not be assumed to be linear. I ran three correlations: between Walk Score® and the walk share for those under 65 (Young Walk Share); the walk share for those 65 or older (Old Walk Share) and the walk share for all adult respondents, regardless of age (Total Walk Share). The sample size for these correlations varied, because some ZIP codes only had data from younger adults (n = 470) and others only had data from older adults (n = 428). For the entire sample, Spearman's correlations indicated that there was indeed a positive relationship between Walk Score® and Walk Share at the ZIP code level (Spearman's r= 0.57). The younger adult subsample also demonstrated a positive relationship (Spearman's r = 0.59), as did the older adult subsample (Spearman's r = 0.44). These results were all significant at the $p < 0.01$ level. The slightly higher Spearman's r for the younger adults indicates a stronger statistical association between walkability and walk share in this age group. At all age groups, though, respondents living in more walkable ZIP codes tended to walk more than their counterparts in less walkable ZIP codes.

Initially, thinking that older adults would be more sensitive to less walkable environments, I had hypothesized that the relationship between Walk Score® and Walk Share would be stronger in the older adult subsample than in the younger adult subsample. Contrary to this hypothesis, comparison scatterplots (Figure 15) indicate no large difference between the two age groups in the steepness of relationship between

Walk Score and Walk Share. The line of best fit is only slightly steeper for the younger adult population than for older adults.

Figure 15: Age comparison of Walk Share and Walk Score®



Chapter 5: Discussion

The purpose of my research was to characterize age based trends, especially for older adults, in active transportation and recreational bicycling in Massachusetts. My overall goal was to provide critical information on current behaviors related to active transportation in older adults that could help the Commonwealth create a built environment supportive to healthy aging.

My results indicated that there are significant differences in transportation behavior between younger and older adults and among different age categories of older adults. My research was suggestive of a link between living in a walkable area and engaging in more transportation walking. This link was observed for adults of all ages. Descriptive maps indicated, however, that the less walkable areas of the state tend to have higher percentages of older adults. A substantial percentage of the older adult population lives in car dependent areas. Spatial variation also exists in how older adults live: urban areas tend to have higher percentages of both older adults living in long-term care facilities and older adults living alone.

Travel Behavior of Older Adults

My results suggest that, among Massachusetts adults, age is related to the overall amount and preferred modes of travel. As measured by trip rate, older adults (ages 65 and above) engaged in significantly less travel than younger adults. Within the older adult population, trip rate declined from younger to older age categories. These differences align with existing research linking aging with fewer trips outside of the home (Farber et al. 2011).

The trend towards decreasing travel with age raises several questions, particularly surrounding the reasons for this decline. Is it because older adults are more

likely to be retired, and therefore do not have to commute to work during the week? Perhaps older adults have more difficulty using most modes of travel and would prefer to stay home for all but the most necessary trips? Future studies, or a more extensive review of the existing literature, could help answer these questions. Existing research does, however, indicate that this declining trip rate may be problematic for many older adults. More often than not, older adults who do not regularly get outside of the home wish that they were able to go out more often (Lynott and Figueiredo 2011). This finding may indicate that, though willing to travel outside of the home, older adults face various barriers to doing so. In other words, the issue is mobility: older adults can't travel safely outside of their home. Low mobility is concerning, because mobility makes it possible for older adults to carry out the activities of healthy aging such as eating a healthy diet, seeing family and friends, being physically active, and accessing the physical locations (doctor's offices, churches and temples, and social service agencies) that make it possible to "tend to mental/spiritual health . . . manage health conditions, and . . . maintain secure finances and housing" (Massachusetts Healthy Aging Collaborative 2014, 7). Low mobility is linked to fewer trips to the doctor and to social, family, and religious activities (Bailey 2004). While my own research did not investigate the reasons behind the declining trip rate among Massachusetts older adults, it seems likely that this decline is at least related to a challenge to healthy aging: lack of mobility.

The primary commonality between all age groups was that driving a car was the preferred mode of travel. Nationwide, driving is the most prevalent mode (NHTS 2009). The comparison of younger versus older adults indicated that driving a car was slightly more prevalent in older adults, yet within the older adult sub-sample, driving tended to decrease with age. The later trend mirrors research linking aging with lower rates of driving (Gibson et al. 2004, cited in Kochera et al. 2005, NHTS 2000, cited in Bailey 2004).

Age-based trends in alternative modes seem, overall, to be more pronounced than those for driving. Older adults had higher rates of being a passenger in a car, using paratransit, and using "other" forms of transportation. Younger adults had higher rates of active transportation – both walking and bicycling – and public transportation. Consistent with the analysis of mode share, transportation bicycling was more prevalent in the younger adult group (below 65) than the older adult group. There was no significant difference, however, in the rate of recreational bicycling between these two groups. Within the older adult sub-sample, some modes of transportation went up and down with age, but the general direction was that walking, bicycling, and public transportation decreased significantly with age, while being a passenger in a car or using paratransit increased significantly with age.

The trend of a decrease in active transportation with age is consistent with existing national research such as the National Household Travel Survey (2009) and studies of several U.S. cities (Xing et al. 2010). Walking accounts for about 10% of the mode share nationwide, while both younger (16.65%) and older adults (11.6%) exceeded this walk share in Massachusetts. Transportation bicycling rates for younger adults in Massachusetts (1.13%) are quite similar to the nationwide all-ages rate (1%); older adult transportation bicycling, at 0.42%, is below this nationwide all-ages rate (National Household Survey 2009, cited in Alliance for Biking & Walking 2014). Investigating whether Massachusetts adults really do have higher rates of walking compared to the entire country could be an avenue for future research. If a significant difference were indeed found, it might be interesting to look at potential factors influencing this difference, such as increased density or cultural differences.

On the other hand, Massachusetts, like the nation as a whole, lags far behind some European countries in older adult active transportation. For instance, in Germany, almost half of all older adult trips are made by foot or bicycle (Pucher and Dijkstra 2000).

Though research has found that older adults have higher rates of recreational bicycling than younger adults, my research indicated no significant difference (Xing et al. 2010). This lack of difference raises a question: if older and younger adults have similar rates of recreational bicycling, then older adults may, overall, be physically able and willing to bicycle at the same rate of younger adults. Perhaps, then, the decrease in active transportation that comes with age is more related to an overall decrease in transportation activity or to a lack of bicycle friendly infrastructure. This theory is supported by a study indicating that more than half of older adults would walk or bicycle more if their neighborhoods had better pedestrian and bicyclist infrastructure (Lynott and Figueiredo 2009).

Though older adults walk for transportation less than younger adults, walking is the second most popular form of transportation (after driving) for older adults 65–67, while it is the third most popular form of transportation (after being driven by another) for the entire older adult sample and for all the other older age groups. In both my study of Massachusetts data and national studies, walking is far more prevalent than public transit use among older adults (NHTS 2000, cited in Farber et al. 2011). The prevalence of walking suggests that if we want to improve the comfort and safety for older adult users of active transportation, it may make sense to prioritize sidewalks and pedestrian infrastructure over bicycle lanes.

The low rates of active transportation among Massachusetts older adults are concerning because they may be an indication of sedentary lifestyles, which contribute to unhealthy aging. It is important to note that, with the exception of the data on recreational bicycling, the MTS data tell us nothing about rates of overall physical activity, exercise, or recreational physical activity: survey respondents who neither walked nor biked could have driven to the gym and worked out for an hour and a half. Overall physical activity tends to decrease with age, so it seems likely that low rates of active transportation

among Massachusetts older adults are indeed reflective of low rates of overall physical activity (BRFSS, cited in Lynott and Figueiredo 2009; Wilcox et al. 2000; Hillier et al. 2014). From a healthy aging perspective, this presumably low rate of overall physical activity is concerning. Among older adults, physical activity and active transportation boost physical health (Huy et al. 2008). Physical activity can help prevent falls (CDC 2014 citing Vellas et al. 1997). It can decrease the risk of Alzheimer's disease (Scarmeas 2009), improve cognitive ability (Angevaren et al. 2008) and improve mental health (Lindwall, Larsman, and Hagger 2011; Massachusetts Healthy Aging Collaborative 2014).

Though overall, Massachusetts older adults are typical of American older adults in having low rates of active transportation, some areas of the state had higher rates of walking than others. The locations with the most walking by survey respondents tended to be areas with more walkable streets. Both younger and older adults living in more walkable areas in Massachusetts tend to engage in more walking for transportation than those living in car dependent areas of the state. This finding mirrors those from existing research (Frank et al. 2009; Hoehner et al. 2005; Hirsch et al. 2014b; Wilcox et al. 2000). Initially, I was expecting that older adults would be more "sensitive" to less walkable environments and be less likely to walk in these places, whereas young adults would be more apt to walk, regardless of whether the environment was walkable or not. Therefore, I hypothesized that the relationship between Walk Score® and walking behavior would be steeper for older adults than for younger adults. In fact, this relationship had similar steepness in the two age groups, as shown in Figure 15.

Spatial Descriptions of the Older Adult Population

Looking at where and how Massachusetts older adults live gives context to my findings on travel behavior. Descriptive maps illustrated that different areas of the state

have different age distributions. Urban areas with high overall populations also often have higher counts of older adults than rural areas (Figure 1). While urban areas may have higher overall numbers of older adults, less dense rural areas tend to have higher percentages of older adults (Figure 2). According to population projections, this trend of the "graying" of low density communities is expected to continue in the next five years (Figure 3, EOEA 2013b).

These low density rural communities are almost all car-dependent according to Walk Score® (Figure 14). My very rough estimate indicated that about 24% of older adults in Massachusetts live in areas that are at least "somewhat walkable" as measured by Walk Score. The remaining 76% of older adults live in car dependent areas. This car dependency poses a problem for the many older adult residents who will end or decrease their driving due to complications of age. The increased transportation costs of providing service to geographically isolated older adults may be a challenge for service providers. Older non-drivers living in the Commonwealth's low density, car dependent and aging communities may be more vulnerable than their counterparts in walkable communities to lack of mobility and low emotional well-being. Older rural non-drivers typically have lower mobility and take fewer trips outside of the home, and this lack of mobility is linked with more feelings of isolation and lower quality of life among non-drivers, but older urban non-drivers are less susceptible to these problems (Bailey 2004; Kochera et al. 2005).

The potential for social isolation among older non-drivers in car-dependent communities may be slightly less of a concern for older adults who are not living alone. Older adults living with another may not have as strong a need for social contact outside of the home as older adults living alone. Encouragingly, it appears that rural areas tend to have lower percentages of older adults living alone and higher percentages of older adults living with at least one other person than do urban areas. Though further spatial and

statistical analysis would need to be undertaken in order to discover whether this is indeed a significant trend, it appears that older adults living alone tend to be more likely to live in urban areas, where it would be easier to socialize and access services outside of the home without a car.

Denser areas also appear to be more likely to have long term care facilities for older adults. As compared to rural areas, the older adult population in urban areas often has a higher percentage of older adults living in long term care facilities. If this trend is indeed present and significant, it may also be a good thing. Most of those living in long term care facilities have likely reached the point where they can no longer drive; many may no longer be able to walk. These adults may have limited ability and need to travel away from their nursing home. Those that do, however, would probably be more likely to find sidewalks and more extensive pedestrian or wheelchair infrastructure in urban areas than in rural areas.

Limitations

The spatial trends I observed in my maps are based purely on the visual patterns I saw: I did not use spatial statistics to examine clustering. The descriptive, rather than analytic, nature of the spatial component of my project allows me to put forth hypothesis and suggestions for further research, but limits the conclusiveness of my findings.

My estimates of the percent of older adults living in walkable as opposed to car dependent areas were limited by the different spatial units of analysis of the two layers I was comparing: Walk Score® data were in ZIP code polygons, but population data was in census tract polygons. These two different polygons did not always align, so my results did not count those older adults who lived in a census tract that partially overlapped with a walkable ZIP code.

My research on Walk Score® and travel behavior was cross-sectional, so it cannot be used to establish a causal relationship between a walkable built environment and increased walking for transportation. As my travel behavior analyses were based on survey data, non-response bias is a limitation. Though I look at my results in light of other quantitative travel behavior studies, this comparison cannot be used to draw conclusions about differences between travel behavior in Massachusetts and other locations because of differences in the methods of each survey. Another limitation of my results is that, due to lack of data, I did not look at rates of bicycling across the older age categories. If future surveys could obtain better quality data on older adult bicycling, it would be interesting to see at which age older adults tend to stop bicycling due to physical or mental limitations.

Chapter 6: Recommendations and Conclusion

My overarching recommendation is that Massachusetts and its communities plan and implement walkable, older-adult friendly streets. This recommendation is based on the large body of evidence supporting a link between physical activity, active transportation, and healthy aging. Data from other countries suggest that the decline in active transportation with age is not inevitable: in Germany, half of all older adult trips are made using active transportation (Pucher and Dijkstra 2000, 2003). It may be, therefore, that the lower rates of active transportation among older adults in the U.S. are due more to a lack of walkable neighborhoods than to declines in physical ability. In fact, a substantial portion, perhaps up to 76%, of Massachusetts older adults live in car dependent, low walkability areas. Research, including my own, demonstrates a relationship between walkable neighborhoods and increased incidence of walking, among both younger and older adults. This relationship, and the fact that walking is the second or third most popular mode among older adults in Massachusetts, suggests to me that we can be at least somewhat confident that "if we build it, they will come." Older adults are already walking, and if they have safer places to walk, it seems likely that they will walk more. The higher rates of transportation walking (as compared to transportation bicycling) among older adults are the reason that my recommendations focus on walkability rather than bikeability, though both are important.

There are several actors who can influence older adult walkability in Massachusetts, including state-wide agencies, local governments and planning departments, and citizens. I have specific recommendations for each of these groups. Statewide, the Executive Office of Elder Affairs (EOEA) is one of the primary actors who could advocate for older adult walkability. The EOEA's mission statement explicitly mentions healthy aging:

> Empower individuals to make their own choices based upon their preferences and desires and to encourage individuals to make a plan for achieving and sustaining quality of life goals, including aging in place with dignity, financial well-being and healthy aging" (EOEA 2013c, 1).

A needs assessment undertaken by the EOEA demonstrated that transportation, mobility, and physical activity are of primary concern to older adults and agencies serving them (EOEA 2013a). Yet despite these two indications of concern for transportation and healthy aging, there is no evidence indicating that the EOEA has advocated making communities friendlier to older adult pedestrians. References to active transportation or physical activity are absent from the 2014-2017 State Plan on Aging, aside from a somewhat vague objective around fall-prevention: "Promote healthy lifestyles, behaviors and strategies to prevent falls and fall-related injuries among older adults and people with disabilities" (EOEA 2013a, 45). I would recommend that EOEA prioritize advocating for walkable streets and promoting walking among Massachusetts older adults as explicit goals in future plans. The EOEA, as the state agency in charge of the well-being of older adults, is the logical agency to present older adult transportation needs to the Massachusetts Department of Transportation. It appears, however, that the EOEA focuses more narrowly on providing services to older adults rather than coordinating with other state departments. I would recommend that the EOEA integrate advocacy, particularly advocacy around transportation and active transportation, into its primarily service-based approach. This advocacy could be more compelling if the EOEA adopted a stance similar to the AARP. The AARP calls for complete streets and the integration of transportation and land use planning, believing that these planning measures will improve quality of life and community livability for older adults (Lynott et al. 2009; Lynott and Figueiredo 2011).

Regarding my recommendation that the EOEA encourage older adults to walk more, the EOEA is already linked to a small older adult walking program, run through their partner, the Massachusetts Association of Councils on Aging (MCOA). MCOA's "Keep Moving" walking program is a network of older adult walking clubs in 80 towns (MCOA 2015). The EOEA could partner with MCOA to expand this program, and could involve program participants in advocacy for walkable streets.

My recommendations for cities and towns focus on those communities that have high numbers or percentages of older adults, but are considered car dependent, as measured by Walk Score®. Of all the communities in the state, these may be most at risk for unhealthy aging, because older adults, especially those who do not drive, may have difficulty both accessing the services they need and getting enough outdoor exercise. Unfortunately, up to 76% of older adults in the state may live in these car dependent areas. Improving walkability in these communities may be key to enabling older adults to "age in place," which they tend to prefer over moving to an institutional setting (Keenan 2010). Planning departments can improve walkability for older adults in at least three ways: coordinating with the town's Council on Aging (COA), implementing older adult friendly streetscape improvements in areas where older adults are more likely to walk, and adopting a long-range strategy of smart growth.

COAs are the primary town agency charged with the well-being of older adults. The COA serves as a community and social center, as well as a node for health and social services needed by older adults (EOEA 2014). Efforts to improve walkability for older adults will be most successful if older adults themselves have a strong voice in the planning process. The COA's existing relationships to older adults make it the ideal partner in encouraging older adults to go to public planning meetings, planning board hearings, and town meetings. For those older adults with mobility limitations who may have difficulty attending public meetings, the COA can facilitate transportation or

alternative ways for this population to engage in the planning process. COA directors and staff can also represent the interests of older adults in smaller, committee type meetings that may not be designed for much public input. Based on their work with older adults, COAs know which locations within the town are most important for older adults to access. These may be doctors' offices, grocery stores, the library, certain cafes and restaurants, and the COA itself. With this knowledge, COAs can help planners determine the highest priority streets for older adult friendly pedestrian improvements.

What should these older adult friendly pedestrian improvements consist of? I would recommend that towns use the "Safe Routes for Seniors" standards as a jumping off point, but adapt these standards based on local conditions and citizen input (Transportation Alternatives 2003). These standards include wide, level sidewalks, pedestrian scale streetlights, smooth transitions from sidewalk to street, and count-down pedestrian crossings with leading pedestrian interval. I recommend that towns focus on pedestrian improvements over bicycle improvements, though both are important. The reason is that transportation walking is much more prevalent than transportation bicycling. Though slower, walking requires less coordination and less equipment than bicycling, so it is more accessible to a wider population.

It is almost certainly not economically feasible to bring every single street in any given town to this high level of pedestrian improvement. Furthermore, the low walkability of most car dependent towns is perhaps more linked to their low density, which makes trip lengths prohibitively long, than to a lack of pedestrian infrastructure. In the short term, towns can do little to increase density and walkability, as these would require very large scale development changes. In fact, many of Massachusetts' car dependent towns are rural towns predominated by farms and forests, or "greenfields." It is extremely undesirable, from a smart growth, environmental, and land conservation perspective, to develop homes and businesses on these greenfields. A better short term

option is to concentrate on making the denser and more foot trafficked parts of town hospitable to older adult pedestrians. In many Massachusetts towns, these relatively dense and high foot traffic areas are the traditional town centers, with their churches, town halls, and town commons or greens.

As even my brief outline here demonstrates, issues of older adult walkability are complicated, and interconnected with many of the other transportation and land use planning issues towns face. Therefore, for those communities and regional planning agencies with the resources, it may be beneficial to undertake a planning process dedicated to improving all modes of older adult transportation. An example is the 2009 Merrimack Valley Elderly Transportation study (MVPC 2009). This effort was led by the Merrimack Valley Planning Commission, and involved COA directors from the towns of the Merrimack Valley Region, as well as the Regional Transit Authority, as stakeholders. It identified recommendation actions, including various improvements to public transit and paratransit, safer pedestrian crossings, and transit oriented land use development.

In order to bring about more dramatic changes in older adult walkability, there are several long-range planning initiatives towns could undertake. Primarily, towns could focus on enhancing the residential and commercial density of their centers, and continue to implement walkability improvements on central streets, while preserving their outlying greenfields. Many Massachusetts town centers are historic districts, which may make this task more difficult, as developers in historic districts typically have less latitude to build taller, higher density buildings. Ideally, however, the town could develop older adult housing in these relatively walkable centers. The target occupants for this housing would be older adults already residing in the town who wanted to maintain their social connections in town, but either wanted to downsize and prepare for needing more care in the future, or were already in need of some level of care. A particularly promising strategy might be to have a range of different housing options, all in walkable areas, so

that residents could have a more seamless transition from independent living to various gradations of supportive housing. Long-term care facilities, as my maps indicated (Figure 5), are not distributed evenly across the state. If every town had centrally located, affordable housing catering to the full spectrum from independent living to around the clock care, then it may be easier for older adults to age, if not "in place" at least in their home communities. One of the primary benefits of this land use pattern is that it would cater to the common priority of older adults of living in a walkable area (Keenan 2010).

The most appropriate planning tools to achieve this sort of smart growth would vary depending on the town's current zoning laws, political climate, and development patterns. For towns where most zoning districts do not allow multi-family housing, these techniques could include zoning overlays or new zoning districts where multi-family dwellings and long term care facilities are by right, allowed with site plan approval, or allowed with special permit. Vacant, town owned buildings located near town centers, such as old schools, may be appropriate for retrofitting as older adult apartment buildings or long-term care facilities. Such a retrofit occurred more than twenty years ago in my hometown of Weston.

Towns and town planning departments have limited budgets, and varying degrees of interest and expertise in planning for older adult quality of life and walkability. Citizens concerned about these issues may have to take a more active role in convincing planners to implement walkability improvements. I would recommend that these citizens engage with the public planning process around both streetscape design and longer range, comprehensive planning. My primary recommendation to older adult pedestrian advocates is to know that, according to the best available data in Massachusetts, they are not alone: walking is prevalent among older adults. Therefore, they are justified in advocating for the need for older adult friendly streets. By showing up to a public meeting and suggesting that a certain road crossing be recalibrated for a longer pedestrian

crossing time, they are probably speaking for many other older adults who have the same difficulty crossing that street.

Though I believe that compelling accounts of personal experience are often the most convincing in local public discourse, it could be helpful for advocates to cite the well-established links between walking and health or healthy aging, and walkable streets and increased walking behavior. It may be especially important to emphasize the health, healthy aging, and safety problems of un-walkable streets. Aging, accident, and ill-health touch everyone. We may be more apt to put money and resources into building walkable streets if we fully understand that these streets can help keep us, our parents, and our grandparents healthy and happy into old age.

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