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How Can Employers Contribute to Reducing Commuter-Generated Carbon Emissions? Evaluating Employer-Provided Commuter Benefits in Cambridge, MA

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**HOW CAN EMPLOYERS CONTRIBUTE TO REDUCING
COMMUTER-GENERATED CARBON EMISSIONS?
EVALUATING EMPLOYER-PROVIDED COMMUTER BENEFITS
IN CAMBRIDGE, MA**

A Thesis Presented

by

MARY R. RICHARDS

**Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of**

MASTER OF SCIENCE

September 2020

Geosciences

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ABSTRACT

HOW CAN EMPLOYERS CONTRIBUTE TO REDUCING COMMUTER-GENERATED CARBON EMISSIONS? EVALUATING EMPLOYER-PROVIDED COMMUTER BENEFITS IN CAMBRIDGE, MA

SEPTEMBER 2020

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Encouraging a more sustainable commuter mode shift and improving urban transportation systems have the potential to reduce anthropogenic greenhouse gas emissions (GHGs), a major contributor to climate change. Replacing some single-occupancy vehicle (SOV) trips with alternative modes of transportation, such as public transit, walking, or bicycling, represents one approach to begin reducing transportation-related emissions. Collectively, these shifts in transportation patterns would help to reduce the negative social, economic, and environmental costs associated with high rates of personal vehicle use. Employer-provided benefits programs have the potential to influence commuter behavior by making sustainable, alternative commuting choices a more convenient and economically feasible option. In addition, the implementation of these programs can have broader benefits such as helping to achieve municipal and regional sustainability goals and improving community members' physical health and quality of life.

This study applies qualitative and quantitative analysis to investigate employee commuting behavior in response to employer-provided benefits in Kendall Square, a neighborhood in Cambridge, Massachusetts. The employee and employer survey data analyzed in this research was originally collected by TransAction, a transportation consulting firm in the Greater Boston region. To comply with Cambridge's Parking and Transportation Demand Management (PTDM) Ordinance, TransAction works closely with companies to coordinate and manage onsite commuter services programs and prepare PTDM Annual Reports. The primary objectives of this research are: 1) to introduce the multi-dimensional benefits of re-envisioning the existing transportation networks; 2) to determine the influence of employer-provided

commuting benefits on employee commute mode choice; 2) to provide guidance for employers interested in promoting a more sustainable employee commute mode split; and 3) to present the broader implications and applications of this research for employers, municipalities, and coordinating agencies interested in reducing SOV commuting trips and promoting the use of more sustainable, alternative modes of transportation.

Overall, the findings from this research illustrate that while employers have the ability to promote more sustainable transportation choices among their employees, the complexity of the transportation network (and its interdependencies) requires collaboration among all stakeholders to initiate widespread, comprehensive changes.

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LIST OF ABBREVIATIONS

| | |
|---------------|---|
| AAA | American Automobile Association |
| ACC | Anthropogenic climate change |
| APTA | American Public Transportation Association |
| ASCE | American Society of Civil Engineers |
| BMI | Body mass index |
| BRT | Bus rapid transit |
| CDC | Center for Disease Control |
| CDD | Community Development Department |
| EPA | Environmental Protection Agency |
| GHG | Greenhouse gas |
| IPCC | Intergovernmental Panel on Climate Change |
| IRS | Internal Revenue Service |
| KSA | Kendall Square Association |
| KSURP | Kendall Square Urban Renewal Plan |
| LPT | Lost productive time |
| MAPC | Metropolitan Area Planning Council |
| MBTA | Massachusetts Bay Transportation Authority |
| MIT | Massachusetts Institute of Technology |
| MPG | Miles per gallon |
| NACTO | National Association of City Transportation Officials |
| NGO | Non-governmental organization |
| NHANES | National Health and Nutrition Examination Survey |
| NHTS | National Household Travel Survey |
| PMT | Passenger-miles traveled |
| PTDM | Parking and Transportation Demand Management |
| SFMTA | San Francisco Municipal Transportation Authority |
| SOV | Single-occupancy vehicle |
| TMA | Transportation management association |
| TNC | Transportation Network Company |
| TOD | Transit-oriented development |
| TSP | Transit signal priority |
| UN | United Nations |
| VMT | Vehicle miles traveled |

CHAPTER 1

INTRODUCTION AND SIGNIFICANCE

1.1 Introduction

With over 80% of U.S. residents living in cities, urban transportation affects a large percentage of the population on a daily basis. It is intricately connected to all urban sectors and plays an important role in the development of the social, cultural, economic, and political framework of cities and regions. As a result, the effort to improve current modes of transportation, while also creating more efficient systems, is a growing area of research across a wide variety of sectors and fields of study. This thesis will present the ways companies, governments, and non-governmental organizations (NGOs) are working together to encourage urban climate resilience by creating a more sustainable transportation system and improving mobility options for urban residents. Do these actions, and particularly employer-provided benefits programs, change commuter behavior? The main focus is analyzing commuter behavior in response to employer-provided benefits programs within the larger transportation environment. This project centers upon a case study of the commuting behavior and attitudes toward commuting by employees of companies in Kendall Square, an innovative neighborhood in Cambridge, Massachusetts. The analysis focuses on employee survey data, which was originally collected in 2018 by TransAction Associates, a transportation consulting firm working in the Greater Boston region.

The themes of urban climate mitigation and sustainability connect the different areas of this research and analysis. Together, these concepts are important for understanding how cities can adapt existing urban dynamics to respond to natural and human-produced challenges, while also improving the quality of life in these urban spaces for all residents. Climate mitigation includes efforts and actions aimed at reducing the drivers and effects of long-term climate change, often in the form of lowering greenhouse gas (GHG) emissions. This concept is closely related to urban resilience, which takes into account a city's ability to avoid excessive damage, reduce vulnerability, and recover quickly from adverse conditions and disturbances. Both of these are highly connected and especially important considerations in the face of changing climatic conditions. Urban sustainability is a broad term that encompasses the health and vitality of the social, economic, and environmental components that make up an urban society. Sustainability is a

way of thinking that incorporates responsible actions, behaviors, and development that can satisfy the needs of current generations without compromising the ability of future generations to meet their needs (Brundtland et al. 1987). With both intergenerational and international components, sustainability as a theory integrates a range of considerations such as the responsible use and stewardship of natural resources and ecosystems, the protection and expansion of social equality, engagement, and justice, and the development of ethical and culturally appropriate economic policies that improve quality of life for all individuals.

More recently, in 2015, the United Nations (UN) adopted the Sustainable Development Goals, a set of 17 goals focused on promoting “prosperity while protecting the planet” through a series of ambitious actions and plans (United Nations 2020). Accomplishing these goals as part of the 2030 Agenda for Sustainable Development requires mobilization and coordination among stakeholders at all scales and in all sectors of society (The Sustainable Development Agenda, 2020). One of the three core themes that the UN highlights as necessary to address in the upcoming decades is the climate emergency. Although all 17 of the goals are highly interdependent, “Sustainable Communities and Cities,” “Responsible Consumption and Production,” and “Climate Action” are three that most closely relate to the importance of addressing unsustainable urban transportation practices.

The transportation sector represents one of the largest contributors to GHG emissions, both nationally and globally. To address this challenge, many cities are interested in introducing climate mitigation practices and adopting sustainability planning initiatives that mitigate and reduce transportation-related emissions. Although transportation is a broad topic that serves a diverse set of purposes, home-to-work commuting is an integral component of urban mobility. Researching the most effective ways to adapt the transportation system is an area of opportunity that many cities are pursuing to alleviate congestion in and around the urban core and to allow individuals to access their areas of employment safely and efficiently.

One factor that influences employee commuting patterns is the provision of transportation-related benefits through employer-subsidized commuting programs, the range of benefits offered to employees to offset transportation costs to and from work. This research will focus on the differences in commute mode choice between individuals receiving incentives or subsidies for alternative transportation and those

receiving automobile-oriented incentives, such as free or reduced-cost parking. The efficacy of these programs is determined based on the rate of single-occupancy vehicle (SOV) trips made by employees of the various companies, in comparison to the regional and national rates.

While the focus of this thesis is employee commuting behavior in response to employer-provided benefits programs, these transportation decisions are not made in isolation. An analysis of the spatial patterns will provide additional information about the ways the geographic distribution of the employers and employees may contribute to the success or the inefficacy of these benefits programs. To supplement these findings and understand the ways external characteristics affect transportation patterns, the larger transportation environment of the region, along with the supporting municipal policies, will also be taken into consideration.

1.2 Significance

Overall, this research evaluates the efficacy of employer-provided commuting benefits programs in encouraging more sustainable transportation-related behaviors among employees. It analyzes commuter survey data to understand the role that employer-subsidized alternative transportation programs play in influencing more sustainable commuting choices in Cambridge's Kendall Square. Within these programs, the unique combinations of benefits, incentives, and subsidies are analyzed and evaluated based on the rate of SOV trips.

Although benefits, subsidies, and incentives are all used to reward and encourage desirable behavior, there are slight differences between these three terms. For this thesis, benefits will be used as a broader term that refers to the additional advantages that are offered to employees along with their monetary compensation. Incentives refer to a specific type of benefit that employers offer as a means to motivate or encourage a specific type of work behavior. Subsidies refer to the financial benefits that employers may grant to employees in an attempt to render the cost of transportation more affordable.

While numerous studies are looking at employer-provided commuting benefits programs and the rate of employee usage, few have analyzed employee data from the relatively large number of companies within the geographical context and urban planning practices of this study area. The results of this analysis provide insight into the ways companies in Kendall Square are attempting to accommodate employees'

commuting needs while working within municipal sustainability policies and goals. Understanding the complex dynamics between these various stakeholders and across sectors helps to illustrate the most successful strategies in prompting shifts in commuter behavior at both company and city levels.

This thesis examines the general commuting patterns in Kendall Square and studies the relationship between employer-subsidized transportation programs, municipal policies, and employee travel choices. These findings may provide useful lessons for other communities aiming to reduce GHG emissions through planning and sustainable transportation-focused initiatives. They can help to provide a basis upon which local governments and businesses can make informed decisions and changes with the ultimate goal of enabling the development of more sustainable and resilient communities. Practically, this research can help guide the modification and creation of future programs and policies aimed at encouraging and enabling a lower rate of SOV commuting trips, a reduction in GHG gas emissions, and the attainment of municipal sustainability goals.

The interdisciplinary nature of this topic requires an understanding of the previous work done in this highly integrated area of research. This project incorporates aspects of the urban, labor, economic, and transportation subdisciplines of geography, urban planning, policy, land use, civil engineering, and public health. The results of this analysis contribute to the larger contemporary discussion and field of study about the most effective employer-provided benefits programs and municipal policies in motivating changes in commuter behavior. Ultimately, the findings from this research can be used to inform future research within this realm.

CHAPTER 2

BACKGROUND

Over the past century, the world's population has grown significantly and transitioned from living in primarily rural communities to living in denser, urban areas. This global urbanization trend is well reflected in the U.S. population. Based on the 2010 Census, more than 80% of the population resides in urban areas, which are defined as 50,000 or more people (U.S. Census Bureau 2016). As more of the population transitions to living in and around urban centers, cities are looking toward sustainable development to serve these increasingly dense metropolitan areas and more efficiently allocate available resources. Contexts for analyzing and improving urban sustainability include fields such as urban geography, transportation geography, and climate change studies.

2.1 Urban and Transport Geography

The growth of urban population centers and the continual movement of people and resources have an inherent spatial component, thus placing these areas of study within the fields of urban and transport geography. Urban geography offers one framework through which the formation and evolution of the spatial relationships between urban spaces and those who occupy them, may be examined and explained. Urban geography is a discipline that applies a spatial perspective to understanding the social and environmental processes that define regions and populations at varying scales, ranging from local to global (Jonas, McCann, and Thomas 2015). As a subfield within human geography, it focuses on the interactions between humans and their built and natural environments in population-dense urban settings. Similar to all of geography, which integrates social and physical science concepts, urban geography is a highly diverse, interdisciplinary field due to its wide-reaching applications to a large number of other academic subjects.

Despite the wide range of areas of study within this subfield, one of the main strengths of urban geography resides in its “ability to synthesize many different perspectives so as to advance our understanding of urban phenomena” (Pacione 2005). Urban geography acknowledges the complex phenomena that influence communities across cities and the globe. Studying social and environmental processes requires a broad perspective that recognizes the ways in which internal and external factors interact to shape and enable the development of a cultural and physical landscape (Jonas, McCann, and

Thomas 2015). Urban geography attempts to understand the way these multiscale, multidimensional interdependencies relate and impact one another. Although many urban areas share similar features and challenges due to larger global forces, regions also experience unique concerns as a result of local characteristics (Pacione 2005). It is the intersection of these forces that urban geographers study to better understand the ways the development and continual evolution of urban environments rely on and influence human interactions and contemporary trends.

Transport geography grew as a subdiscipline of geography in the mid-twentieth century, coinciding with the quantitative revolution. As a result of this paradigm shift, many academics within the field of geography shifted from primarily relying on qualitative and descriptive data to placing an increasing focus on spatial science and the application of scientific principles and methods. Although there were scholars interested in this realm of research much earlier, often within the fields of civil engineering and economic geography (William Richard Black 2003; Goetz 2006; Curl and Davison 2014), the growth and emergence of this subfield is often associated with Edward L. Ullman and Harold Mayer's landmark chapter titled "Transportation Geography," in *American Geography: Inventory and Prospect* in 1954 (Ullman and Mayer 1954; William Richard Black 2003; Goetz, Vowles, and Tierney 2009). Both Ullman and Mayer studied as geographers at the University of Chicago in the mid-twentieth century and became leading scholars in the fields of urban and transport geography throughout the late twentieth century. In their 1954 work, they emphasized the importance of transport and circulation as centralizing themes within the field of geography due to their focus on the spatial distribution and interchange of resources (Ullman and Mayer 1954; Rodrigue, Comtois, and Slack 2013). William Garrison was another notable figure who greatly contributed to the field of transport geography during this time period. As one of the leading geographers in the quantitative revolution, Garrison's research primarily focused on the role of transportation in shaping economic development by employing spatial analysis and quantitative models. Some of his best-known works contributing to this newly developing subfield include a series of papers in which he reviewed the spatial arrangement of economic activity (Garrison 1959a; 1959b; 1960). Collectively, these well-known scholars emphasized the importance of studying and understanding the ways differing degrees of connection between areas and people can help to explain regional patterns.

Early transport geography, which emerged from economic geography, focused on the facilitation and distribution of social and economic activity via transportation networks (Knowles, Shaw, and Docherty 2008; Rodrigue, Comtois, and Slack 2013; Wheeler 1976). With the emergence of critical geography in the 1970s, the perspective and scope of transport geography coevolved to reflect the contemporaneous social trends and cultural shifts, including the environmental and civil rights movements. In the second half of the twentieth century, transport geographers began to consider the impact their research has on the environment and the subfield's overall role in sustainability (William R Black 1996; Mohan and Tiwari 1999; Keeling 2008). A heightened awareness that different groups of people experience varying degrees of accessibility and mobility, often based on their identity and access to resources, also began to enter into the larger conversation (Farrington 2007; Aldred and Woodcock 2008; Delbosc and Currie 2011; Welch and Mishra 2013; Pyrialakou, Gkritza, and Fricker 2016; El-Geneidy et al. 2016; Oswald Beiler and Mohammed 2016; Mei-Po Kwan and Schwanen 2016). The inclusion of and expansion upon these considerations into equitable and just systems highlights the influence of ongoing cultural conversations surrounding social justice and environmental responsibility.

Due to the spatial component and interdisciplinary nature of their research, urban and transport geographers contribute a unique perspective when studying many of the challenges that cities are facing today. These research frameworks are especially important when trying to understand and develop theories that explain the complex and interdependent linkages connecting goods, people, and ideas in the era of globalization and climate change.

2.2 Climate Change and Transportation

Together, the concepts of urban climate resilience and sustainability are important for understanding how cities can adapt and respond to natural and manmade challenges, while also improving the quality of life within these urban spaces. Climate change is one of the major contemporary issues that many cities are attempting to address through innovative design and planning.

It is well-recognized that natural factors contribute to climate change; however, over the past few decades, there is increasing evidence and a growing consensus that climate change is also closely related to anthropogenic factors. In 2004, Oreskes published a study investigating the abstracts of 928 peer-reviewed

scientific articles published between 1993 and 2003, with the keywords “climate change.” She found that 75% either explicitly or implicitly accepted the consensus view that human activity is significantly impacting Earth’s climate, while the remaining 25% took no position on anthropogenic climate change (ACC), and none of the papers disagreed outright (Oreskes 2004). In 2010, Anderegg et al. found that 97 to 98% of the most actively publishing climate researchers support the consensus view held by the Intergovernmental Panel on Climate Change (IPCC). In addition, the authors of this PNAS study investigated the relative climate expertise of the 1,372 climate researchers agreeing with and discounting anthropogenic climate change. The expertise and prominence of the scientists supporting ACC were substantially higher than the researchers who disagreed or remained unconvinced of ACC (Anderegg et al. 2010). In 2016, Powell assessed peer-reviewed climate change literature published between 1991 and 2015. He found that there was an average consensus of 99.84% of the 54,195 articles published in the 25-year period, with only 31 dissenting articles (Powell 2016). Therefore, based on the most recently published survey of climate change literature, more than 99% of actively publishing climate scientists agree that increased GHG concentrations in the atmosphere and the resulting effects of climate change can be attributed to human activities.

One of the main GHG contributors is the combustion of fossil fuels such as coal and oil (NASA 2020). In 2010, the transportation sector was responsible for about 23% of the total global energy-related CO₂ emissions (Sims et al. 2014). In the United States, the transportation sector generates 29% of the total GHG emissions and of those, passenger cars and light-duty trucks are the largest contributors, accounting for 59% of the country’s transportation sector emissions (“Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions 1990-2017” 2019). Because this sector generates the largest share of GHG emissions, reducing transportation-related emissions is becoming a critical focus for many of the cities that are interested in lowering their carbon footprints and reducing their environmental impact.

Cities are increasingly incorporating climate change considerations into their urban planning efforts and priorities. As a result, sustainability and climate mitigation represent some of the major organizing principles of these long-term plans and city-wide goals. This can be seen in the wide range of membership organizations, networks, and agreements that join cities across the country and around the world, all with a common focus on sustainability, resiliency, and GHG mitigation. Some examples of these

networks include national organizations and certification systems such as Climate Mayors, Sustainable Healthy Cities, and LEED for Cities & Communities program (formerly STAR communities), and international networks and agreements such as C40 Cities, 100 Resilient Cities, and the Paris Agreement (Climate Mayors 2019; Sustainable Healthy Cities Network 2018; “Certified STAR Communities” 2016; C40 Cities Climate Leadership Group 2019; The Rockefeller Foundation 2020; United Nations Framework Convention on Climate Change n.d.). Although reducing transportation-related GHG emissions is not the only area of focus for these groups, it is frequently listed as one of the main considerations for addressing urban sustainability.

Because GHG emissions and the transportation sector are closely related, cities often include improving the efficiency and accessibility of transportation networks as an essential component of their sustainability initiatives. One way in which municipalities are approaching these goals is the adoption of Parking and Transportation Demand Management (PTDM)-related efforts and programs. While PTDM encompasses a variety of strategies, the main goals of these programs and policies are to reduce parking demand while encouraging a shift in commuting patterns towards more sustainable, alternative forms of transportation. Therefore, through the use of thoughtful planning and development strategies that encourage the use of public transportation and discourage the use of personal vehicles, cities are attempting to offer opportunities for residents to make more sustainable transportation-related lifestyle choices.

2.3 Benefits of Alternative and Active Transportation

In this thesis alternative transportation or commuting refers to the use of public transit, cycling, and walking. Active transportation or active commuting refers to traveling by cycling or walking. Alternative and active modes of transportation have multiple benefits for employees, employers, and the environment. In addition to the environmental benefits gained from switching to alternative modes of transportation and reducing GHG emissions, there are numerous societal benefits.

2.3.1 Public Welfare

2.3.1.1 Reducing GHG Emissions

In the United States, the transportation sector plays a large role in producing GHG emissions, thus contributing to climate change. GHG emissions are associated with almost all mechanized forms of transportation. Although public transportation systems require energy, often in the form of fossil fuels, they generate significantly fewer GHG emissions than personal vehicles when comparing passenger-miles traveled (PMT) (Hodges 2010).

Based on a 2015 report published by the Environmental Protection Agency (EPA), the average fuel economy for a gasoline-powered passenger vehicle in the United States is 22 miles per gallon (mpg) (“What If We Kept Our Cars Parked for Trips Less Than One Mile?” 2015). When one gallon of gasoline is burned, approximately 8,887 grams of CO₂ are emitted, which translates to approximately 404 grams, or just under one pound, of CO₂ emitted per mile traveled (“What If We Kept Our Cars Parked for Trips Less Than One Mile?” 2015; Hodges 2010).

About 46% of vehicle trips are under three miles and 21% of car trips are one mile or fewer (Federal Highway Administration 2018). According to the 2009 National Household Travel Survey (NHTS) data, car trips under one mile are responsible for over 10 billion passenger vehicle miles per year. Assuming the same average fuel economy (22mpg), replacing half of these under-one mile trips with active transportation modes or reducing vehicle miles traveled (VMT) by 20% could reduce national annual CO₂ emissions by about four billion pounds (“What If We Kept Our Cars Parked for Trips Less Than One Mile?” 2015; Grabow et al. 2012). Also, shorter trips generate disproportionately higher emissions due to cold starts, or the amount of energy that is required for the vehicle’s engine to reach the appropriate operating temperature (de Nazelle et al. 2010; Grabow et al. 2012). Therefore, replacing these relatively short automobile trips with AT or public transit options provide one way to reduce personal GHG emissions.

Shifting to alternative forms of transportation represents one of the most effective transportation changes that individuals can make to reduce their carbon footprints, thereby benefiting the environment from a sustainability and conservation standpoint (Hodges 2010; Litman 2019). If public transportation ridership were increased by 9% or 25%, one 2016 study forecasted that by 2050, the cumulative CO₂

emissions could be reduced annually by about 844,000 or 67.6 million U.S. tons (1.7 or 14.8 billion pounds), respectively (Ercan, Onat, and Tatari 2016). In Montreal, Canada, researchers observed that infrastructural improvements to the bicycle network (7% increase in length) resulted in a reduction in GHG emissions (2%) (Zahabi et al. 2016). In addition to the reduced GHG emissions, lower rates of personal vehicle use also help to lessen congestion, thereby reducing air and noise pollution, two automobile-related externalities that disproportionately burden vulnerable populations (Sider et al. 2015; Pratt et al. 2015; Bae et al. 2007).

2.3.1.2 Improving Public Safety

Public safety is another benefit associated with public transportation. In 2017, there were over 37,000 crash-related fatalities and over 2.7 million injuries in the United States (National Highway Traffic Safety Administration 2019). In 2013, fatalities resulting from motor vehicle crashes equated to \$44 million in medical, work, and emotional-related burden costs (“State-Specific Costs of Motor Vehicle Crash” 2015). Although the fatality rate per 100 million VMT has been decreasing over the past few decades, these crash-related fatalities and injuries remain high in part because of the farther distances people are traveling (National Highway Traffic Safety Administration 2018; Bureau of Transportation Statistics 2018). When considering unintentional injury deaths across all age groups in the United States, motor vehicle crashes represent the 4th overall leading cause of death (National Highway Traffic Safety Administration 2018).

Between 2008 and 2017, the biggest change in fatality composition was the increased proportion of pedestrians, bicyclists, and other nonoccupants (National Highway Traffic Safety Administration 2018). This finding supports the results of a study in which bicyclists and pedestrians were 2.3 and 1.5 times, respectively, more likely to be fatally injured when compared to passenger vehicle occupants (Beck, Dellinger, and O’Neil 2007). In this study, researchers used 2001 NHTS data to calculate relative traffic injury risk by mode. To further quantify the injury risk associated with different modes, Chu (2009) calculated that exposure to motor vehicles equates to about \$2.00 of expected injury costs per hour compared to the lower risk of \$1.69 per hour associated with walking.

In comparison to traveling by passenger vehicle, bicycle, walking, motorcycle, or other vehicles, traveling by bus is the safest mode, accounting for the smallest proportion of injuries and fatalities (Beck,

Dellinger, and O’Neil 2007). A study conducted in Montreal confirms the relative safety of riding the bus for vehicle occupants, cyclists, and pedestrians when compared to commuting by car (Morency et al. 2018). For car travel, 5.1 people are severely or fatally injured per hundred million car passenger-kilometers, compared to the much lower rate associated with bus travel, which was calculated to be 1.0 injured per hundred million bus passenger-kilometers.

These results suggest that reducing the amount of SOV traffic has the potential to increase public safety, in conjunction with improvements to existing policies, enforcement systems, and roadway design. Creating systems that support multimodal travel can encourage behavioral shifts away from personal vehicles and they have the potential to create safer environments for people using alternative modes of transportation.

2.3.2 Public Health

There are numerous physical and mental health benefits, such as lower cardiovascular risk and lower stress, that can be gained from choosing alternative modes of transportation and incorporating more physical activity into the daily commute. Active transportation modes in particular, such as cycling, are correlated with mental and physical well-being (Mytton, Panter, and Ogilvie 2016a).

2.3.2.1 Physical Health

2.3.2.1.1 Cardiovascular Health

Physical health is negatively correlated with commuting by car. In a study of Australian adults over 4 years, weight gain was significant for daily car users in comparison to non-car and occasional car commuters (Sugiyama, Ding, and Owen 2013). In addition to weight gain, longer amounts of time spent in cars on a daily basis correlates with significantly higher cardio-metabolic risk, quantified by markers such as total and central adiposity, waist circumference, blood pressure, and body mass index (BMI) (Sugiyama et al. 2016).

In the United States, the Center for Disease Control (CDC) identifies obesity as a “common, serious, and costly” public health concern (“Adult Obesity Facts” 2020). Among adults, the age-adjusted prevalence of obesity and severe obesity, defined as BMIs equal to 30 or greater or equal to 40 or greater, is

42.4% and 9.2%, respectively (Hales et al. 2020). Over the past two decades, between 1999-2000 and 2017-2018, obesity and severe obesity increased from 30.5% and 4.7%, respectively. For reference, BMIs between 18.5 and 25 are considered to be healthy, while those between 25 and 30 are considered to be overweight (“Defining Adult Overweight and Obesity” 2020).

In contrast to commuting by personal vehicle, active transportation is associated with numerous health benefits. Some of these health benefits include preventing weight gain (Mytton, Panter, and Ogilvie 2016b), lower BMI and percentage body fat (Andersen 2016; Mytton, Panter, and Ogilvie 2016b; E. Flint and Cummins 2016), lower probability of obesity, diabetes, and hypertension (Tajalli and Hajbabaie 2017; Furie and Desai 2012), and maintaining more favorable cardiovascular health profiles (Furie and Desai 2012; Brockman and Fox 2011). In comparison to car-only commuting, cycling is the most protective against obesity, followed by walking and mixed-modes (E. Flint and Cummins 2016). These results confirm the findings from a previous study in which researchers determined a direct correlation between the degree of health benefits and the intensity of activity. Based on the National Health and Nutrition Examination Survey (NHANES), individuals engaging in higher levels of active transportation experienced greater benefits and health outcomes than those categorized in the low and no active transportation groups (Furie and Desai 2012).

Commuting by active travel modes provides an opportunity for individuals to accumulate and achieve the recommended levels of physical activity (Andersen 2016; Sahlqvist, Song, and Ogilvie 2012). The Department of Human and Health Services recommends a minimum of 150 minutes of moderate-intensity aerobic activity to gain health benefits ranging from improved cognitive function and reduced anxiety to a reduced risk of developing chronic diseases (Rodgers 2018). Although increased physical activity is beneficial for everyone and is associated with an improved quality of life, encouraging the use of active commuting modes (walking or biking) as part of employees’ daily routines could result in even greater impacts for the highest-risk populations that may not engage in other forms of exercise (Furie and Desai 2012). In a study investigating the University of Bristol staff surveys, researchers determined that over 70% of the respondents reporting the regular use of active commuting modes, met over 80% of their weekly recommended physical activity through their commute alone (Brockman and Fox 2011). Based on

these results, increasing active commuting could have large health benefits both at an individual and population scale.

While commuting by personal vehicle and active modes are associated with negative and positive health outcomes, respectively, the use of public transit is correlated with diverging health outcomes, depending on the mode. When compared with commuters using private transportation in New York City, subway users exhibited a lower probability of being obese and having diabetes, while those using the bus exhibited a higher probability of being obese (Tajalli and Hajbabaie 2017). Although these results are statistically significant, they are likely the result of the more complex, underlying socio-demographic and transit accessibility spatial patterns within urban areas. The association between transit modes and differing health outcomes have important policy implications in terms of urban equity and access to resources.

2.3.2.1.2 Air Quality

Shifting to alternative forms of transportation has the potential to reduce congestion on the road, thereby reducing GHG emissions and air pollution, and improving public health outcomes at a regional scale (Ercan, Onat, and Tatari 2016; Johansson et al. 2017). Public officials and economists quantify the benefits from improving air quality and reducing exposure to air pollution in the number of lives that could be saved annually and the amount of money that could be saved by improving public health. These common forms of health-related measurements provide a consistent way to provide context and illustrate the magnitude of positive impact.

Johansson et al. (2017) calculated that over 400 lives could be saved annually if employees commuting short distances, corresponding to a 30-minute bike-ride or shorter, transitioned from driving to biking. This model allowed the authors to calculate the reduction in population exposure and the years of life saved based on established health impacts from vehicle emission exposure (Johansson et al. 2017). Similarly, researchers studying urban areas in Midwestern states determined that replacing half of round-trip car trips under five miles with bike trips would increase physical activity to levels that would reduce deaths and health care costs within the study region by approximately \$3.8 billion/year (Grabow et al. 2012). Within the same study, the improved physical fitness and improved air quality within the study region were estimated to be worth over \$8.7 billion annually.

While there are some risks associated with the utilization of active transportation modes due to increased exposure to traffic accidents and air pollution, the projected net health benefits far outweigh these risks (Mueller et al. 2015). Decreasing the rate of SOV travel while increasing the rate of travel by active transportation modes further reduces these health and safety risks, as road users become more accustomed to the use of these alternative modes, and those using active transportation modes become more comfortable as their numbers grow. In the case of traveling by bicycle, there is often safety in numbers. Increasing the number of cyclists increases their visibility and presence, which increases cycling safety and comfort, and has the potential to further increase the use of this mode within one's community (Pucher, Dill, and Handy 2010). This represents a positive feedback loop where the adoption of these more sustainable modes reduces the reliance on personal vehicles, thereby making the overall transportation environment safer for those using these sustainable modes. Enhanced streetscapes and pedestrian environments also help to promote changes in commuting behavior, resulting in co-benefits, such as increased physical activity and health (de Nazelle et al. 2010).

2.3.2.2 Mental Health

2.3.2.2.1 Commuting Modes

The transportation mode that employees choose significantly influences their satisfaction with their commute, thus indirectly impacting emotional well-being and life satisfaction (Friman et al. 2017; Ettema et al. 2011). Although the purpose of commuting is to travel between an employee's home and work locations, research indicates that there are benefits that extend beyond the basic mobility function of transportation (Páez and Whalen 2010; St-Louis et al. 2014). If individuals approach their commute as having a greater value than simply arriving at their destination, they are more satisfied with their travels, regardless of the mode (St-Louis et al. 2014). Because of this finding, the authors emphasize the importance of framing these supplemental benefits when aiming for greater satisfaction and a more sustainable mode shift. In addition, leveraging the aspects of the commute mode that employees appreciate can help to encourage more widespread adoption and support of these alternative modes. For example, encouraging active transportation modes can work toward improving both emotional well-being and life satisfaction by positively influencing travel satisfaction (Friman et al. 2017).

Commuters using active forms of transportation, such as bicycling and walking, are significantly more satisfied than those driving personal vehicles (Ye and Titheridge 2017; O. Smith 2017; Páez and Whalen 2010; St-Louis et al. 2014). Based on a survey of employees in Portland, OR, those traveling by active modes were significantly happier with their commutes than bus and car users (O. Smith 2017). And although driving often takes less time and effort than alternative modes (Maciag 2017), one study of students in Canada concluded that active travelers are more accepting of longer trip durations, partially due to the enjoyment they experience as part of their commute (Páez and Whalen 2010). When compared with walking and public transportation, driving is the most stressful mode of transportation (Legrain, Eluru, and El-Geneidy 2015; A. Martin, Goryakin, and Suhrcke 2014). Among New York City commuters, those traveling by car experienced significantly increased levels of reported stress and more negative moods, in comparison to those commuting by train (Wener and Evans 2011). In another study of New York City commuters, the probability of having mental disorders is significantly lower among commuters choosing to walk when compared to those using private transportation (Tajalli and Hajbabaie 2017).

Although many studies agree about the physical and emotional benefits of active transportation, the conclusions involving commute satisfaction with public transit are conflicting. Friman et al. (2017) found that transit commuters have the lowest commute satisfaction when compared to employees using active modes and their personal vehicles; however, these results do not account for the differences between transit modes. In addition, other studies reveal that commuters choosing to use different modes of transportation often prioritize and value different aspects of the commute (Ye and Titheridge 2017; Páez and Whalen 2010). While active commuters are less concerned with the amount of time spent in transit because they appreciate the intrinsic value of traveling, car users do not express an appreciation of their commute experience beyond the utilitarian aspect of the trip (Páez and Whalen 2010). In a study investigating commuter satisfaction among faculty, students, and staff at McGill University in Quebec, St-Louis et al. (2014) separated public transit users into three distinct categories: train, metro, and bus. By investigating these different transit modes separately they found that along with pedestrians and cyclists, train commuters were significantly more satisfied than those traveling by SOV, metro, and bus. By providing further insight into the attitudes and preferences of travelers, these results have important policy implications for encouraging more sustainable commuting behavior and improving well-being.

2.3.2.2.2 Commuting Time and Reliability

In addition to commuting mode, the amount of time spent commuting directly impacts well-being as trip duration correlates positively with stress, fatigue, and mood (Stone and Schneider 2016; Morris and Guerra 2015; Ettema et al. 2011). The average American spends 26.6 minutes a day commuting one-way to work, a value that has steadily increased over the past decade (U.S. Census Bureau 2018e). Commute duration is much higher for those commuting in urban areas, such as Suffolk and Middlesex Counties in Massachusetts, the counties encompassing Boston and Cambridge, respectively. The average one-way commute for individuals in these counties are 31.1 and 30.9 minutes, respectively (U.S. Census Bureau 2018e).

Longer commute duration, increased time pressure, and higher levels of unpredictability have a significant negative impact on commute satisfaction (Morris and Guerra 2015; St-Louis et al. 2014; Ettema et al. 2011; Wener and Evans 2011). In a study of commuters using six different transportation modes, St-Louis et al. (2014) conclude that users of all modes are negatively impacted by longer travel times. Despite this, certain modes (personal vehicle, metro, train) are more negatively impacted than others (walking, cycling, bus) because of additional trip characteristics, such as weather conditions, cost, and the required number of transfers (St-Louis et al. 2014).

Beyond commute satisfaction, Lorenz (2018) argues that commuting distance and duration negatively impact cognitive well-being. As an increasing amount of time is allocated to commute farther distances, less time is available for leisure and family-related activities. Having the time and energy to engage in personal pursuits and hobbies, beyond family and work-related responsibilities, are essential for maintaining a healthy work-life balance.

Reducing travel time and congestion represent two approaches to alleviate stress among employees, thus improving commute satisfaction and improving overall well-being (Morris and Guerra 2015; Lorenz 2018; St-Louis et al. 2014). When studying undergraduates in Sweden, researchers found that travel mode and travel time directly influence the quality of travel and commute satisfaction (Ettema et al. 2011). Because of the complexity of these challenges, there are a variety of approaches to increase commute well-being. Within the regional transportation network, increasing the predictability of transit modes and reducing commuter effort are strategies that have the potential to improve employee well-being

(Wener and Evans 2011; Ettema et al. 2011). Because St-Louis et al. (2014) found that commute satisfaction is lowest among metro and bus users, the authors suggest that focused actions to reduce the travel times associated with these modes would yield the best results in terms of improving commute well-being. From a longer-term, larger-scale perspective, implementing policies that address land use and reduce congestion, in order to shorten trip distances and to lower commute duration, is an additional consideration (Morris and Guerra 2015).

2.3.3 Equity

2.3.3.1 Costs of Automobile Culture

Among the socio-demographic factors influencing mode choice, “vehicle ownership is the dominant factor affecting travel mode choice in both direct and indirect ways” (Ding et al. 2017). Throughout much of the country driving is the default mode of transportation. To accommodate for this automobile-focused development, the government heavily subsidizes owning personal vehicles through tax revenue. According to the Bureau of Transportation Statistics, the government allocated \$355.7 billion to transportation programs in 2014 (Sprung and Chambers 2017). While a small majority of these funds (\$183.6 billion, 51.6%) were collected from transportation-related activities, the remaining amount (\$172.1 billion, 48.4%) came from other sources unrelated to transportation, including state and local sales and property taxes. Therefore, roadway user fees finance approximately half of the total roadway costs through fees, such as fuel taxes, vehicle registration costs, and tolls. Based on 2008 roadway figures, the money generated from vehicle users to fund highway maintenance and construction averaged 3.3 cents per vehicle mile, while total expenditure averaged 7.5 cents per vehicle mile (Litman 2020b).

Because of the way that automobile-related infrastructure is funded, a Harvard Kennedy School research study estimates that the total cost of the motor vehicle economy in Massachusetts is approximately \$64 billion. This translates to \$14,000 annually per family, regardless of their vehicle ownership status (Olson et al. 2019). This high value includes both the direct (maintenance and operating costs of road infrastructure, land value) and the indirect costs (injuries and deaths, congestion, pollution, GHG emissions, lost productivity) associated with vehicle use.

For those with vehicles, the consumer costs are even greater. Many automobile-related fees are overlooked by drivers, such as insurance, registration, taxes, fuel, and routine maintenance. In 2015, owning and operating a vehicle cost approximately 57 cents per mile (Sprung and Chambers 2017). Because the average American drives about 15,000 miles annually, the American Automobile Association (AAA) estimated that owning a car costs the average American about \$8,000/year (Edmonds 2017).

2.3.3.2 Disproportionate Costs

The fact that road users do not fully pay for the system's costs highlight the inequities of the transportation system as a whole. Lower-income households are less likely to own a vehicle ("Household, Individual, and Vehicle Characteristics" 2017). Although these households do not have to pay for consumer costs, they still support the vehicle economy by contributing to the transportation funding gap through their taxes and they disproportionately bear many of the externalities associated with automobile culture.

Understanding how current policies and funding decisions influence the transportation system is important when trying to improve mobility and encourage a major shift in commuting behavior. According to the Bureau of Transportation Statistics, highways receive the majority (75%) of government-funded investment. In 2014, 9.7% of federal transportation expenditures was allocated to highways and 0.4% was allocated to transit. State and local expenditures went primarily to highways (70%), with less than half of that going to transit (20%) (Sprung and Chambers 2017). Because of the different standards and metrics used to prioritize transit and highway projects, there is often a comparison bias in favor of road projects ("Why and How to Fund Public Transportation" 2009). Public transit is expensive and cannot pay for itself, similar to the highway system. According to the National Transit Database, the average farebox recovery ratio, or the percentage of money generated from passenger fares that cover operating costs, is 33% (Office of Budget and Policy 2019). Although both roads and public transit are subsidized, opponents of public transportation often believe that these systems should pay for themselves, without applying this same logic to other forms of transportation.

Therefore, rethinking the transportation system requires prioritizing a more equitable system that provides viable transportation options for all populations. Providing greater access to resources and employment for disadvantaged groups is one way to help mitigate the inequities that are inherent in the

vehicle economy. Also, creating a more supportive environment for alternative modes of transportation could ultimately lead to lower personal vehicle ownership, which would have numerous social and environmental benefits.

2.3.4 Employee Productivity

Because this research is focused on employer-provided programs to encourage more sustainable modes of transportation, it is also important to acknowledge how improving the general transportation system can be beneficial to employers. Measures that encourage active commuting can lead to a healthier and more productive workforce, an especially important consideration with the high rate of obesity among American adults. In this research, active commuting refers to cycling and walking to work. Active commuting can lead to increased physical activity, both of which are associated with better physical and mental wellbeing, and with fewer absences from work due to sickness (Mytton, Panter, and Ogilvie 2016a; Neha Mukesh and Fehmidah 2014). More specifically, cycling to work is associated with fewer sickness-related absences per year when compared to individuals using other modes (Mytton, Panter, and Ogilvie 2016a; Hendriksen et al. 2010).

In the United States, physical inactivity among adults was conservatively estimated to cost over \$251 billion, in 2003 dollars (Chenoweth and Leutzinger 2006). Researchers based this calculation on a seven-state cost analysis, taking into account medical care, workers' compensation, and productivity loss. When combined with excess weight, Chenoweth and Leutzinger (2006) approximated that the total national cost is more than \$507 billion, in 2003 dollars. The large financial burden of inactivity and obesity impacts employers as a result of direct health care costs and indirect costs. Economists and public health officials calculate that obesity alone costs society \$149 billion in medical expenses per year and lowers on-the-job productivity by about \$66 billion (Trust for America's Health 2018). The correlation between employee health and lost productive time (LPT) is also important to consider as obese workers were estimated to cost employers an additional \$11.7 billion compared to their normal-weight coworkers (Ricci and Chee 2005). These values show how promoting healthier behavior such as AC could reduce the amount of LPT and medical costs per employee.

By providing thoughtful benefits packages that incentivize and subsidize certain transportation modes, employers have the ability to influence their employees' commuting patterns. Promoting the use of more sustainable and healthier commuting modes is beneficial for employees, employers, and the larger region, both from public health and environmental standpoints.

2.4 Employer Benefits, Incentives, and Subsidies

2.4.1 Historic and Contemporary Trends

Transportation benefits programs fit within a long history of employer-provided subsidies and incentives. Over time, the labor market has coevolved with the labor pool to provide benefit and subsidy programs to recruit and retain talent. These perks and benefits range from the more traditional, such as health insurance, disability, retirement, and paid time off, to the more innovative, such as profit-sharing, flexible work schedules, free meals and snacks, wellness reimbursements, and commuting subsidies. Within the last few decades, a growing number of startups and increased attention to employee happiness highlight the importance of providing creative benefits packages.

These benefits are often used as a measurement when ranking the “best workplaces” more recently becoming a source of competition among companies trying to provide the best work environment to acquire and retain the best workforce. As a result, employer-provided benefits are one of the driving forces of the labor market. According to an Employment Confidence Survey, 79% of employees indicated that they would prefer new or additional benefits to a pay raise, with younger generations seeing benefits more favorably than older employees (Glassdoor Team 2015). For young millennials, those who graduated college within the last two years or will be graduating in the next 12 months and are seeking employment, a 2018 survey conducted by American Institute of CPAs concluded that health insurance, paid time off, and student loan forgiveness were the three most desired workplace benefits (American Institute of CPAs 2019). In addition, the study also reveals that over two-thirds of this cohort anticipate that employer-provided benefits will increase over time.

Unlike supplemental benefits and incentives that are influenced by market forces and which may become limited when the labor supply is abundant and prospective employees are competing for a limited number of jobs, the commuting benefits offered by many Cambridge companies are slightly different.

While they are still offered to employees to encourage better behavior and provide attractive benefits, they are also the result of federal policies and the City's efforts to reduce GHG emissions by promoting sustainable transportation. Therefore, although there are some similarities with the standard employer-provided benefits, municipal and federal programs and policies play an important role in influencing companies' decisions in offering commuting benefits.

According to the American Public Transportation Association (APTA), "most employers who provide transit benefits do so through a pretax program" (Grisby 2017). A federal law (Internal Revenue Code section 132(f)), incentivizes employers to provide commuting benefits, one of eight tax-free fringe benefits. This encompasses (1) commuter highway vehicle transportation between an employee's residence and place of employment, (2) transit passes, and (3) qualified parking ("Publication 15-B: Employer's Tax Guide to Fringe Benefits, For Use in 2020" 2019). When employers voluntarily provide these transportation benefits programs, they may exclude these deducted amounts, up to a certain limit defined by the Internal Revenue Service (IRS) (\$270 per month in 2020), from the company's payroll taxes. In addition to benefiting employers, these programs also benefit employees by allowing them to exclude their transportation costs from their gross income, saving on federal income taxes. Although such pre-tax programs can go a long way in encouraging the use of alternative modes of transportation, this research investigates the influence of benefits and subsidies beyond those cited above. The analysis presented in this thesis focuses on employee behavior in response to employer-provided commuting benefits, such as free parking and transit passes, where employers see the inherent value in the more immediate and tangible support they can provide beyond the promise of a tax benefit.

2.4.2 Trying to Shift Commuting Behavior

Employer-provided benefits strongly influence employee behavior and commuting mode choices (Brueckner and Franco 2018; Hamre and Buehler 2014; Bueno et al. 2017). These benefits packages are widely recognized as a key component in promoting sustainable transportation, especially among daily commuters (Bueno et al. 2017). Encouraging sustainable travel-related commuting choices are most successful when alternative forms of transportation, such as public transit, walking, and cycling, are prioritized over personal vehicles (Su and Zhou 2012). When alternative modes are made more convenient

and attractive to users, by lowering the cost (time and money), increasing accessibility, and implementing larger-scale service improvements, commuters are more likely to choose these options instead of driving (Herzog et al. 2006; Hamre and Buehler 2014). Strategies to reduce private vehicle-related incentives, such as eliminating free or subsidized parking, providing cash-out options, or increasing costs related to driving through the implementation of regional-scale congestion pricing or tolls, also provide an effective approach to discourage SOV commuting (Panter, Desousa, and Ogilvie 2013; Evangelinos et al. 2018; Habibian and Kermanshah 2013). Although policies and programs that incentivize alternative modes and disincentivize driving are effective in encouraging the targeted behavior individually, the combination of these economic-based approaches are more effective in promoting sustainable transportation behavior (Conti 2018).

CHAPTER 3 GEOGRAPHIC CONTEXT

3.1 Massachusetts and Greater Boston

3.1.1 Regional Transportation Infrastructure

Greater Boston has the oldest subway system in the United States and is frequently listed as one of the top five cities in the country for public transportation. The Massachusetts Bay Transportation Authority (MBTA) ranks as the fourth-largest transit agency in the country based on 2018 ridership data; the Greater Boston region ranks as having the fourth highest ridership per capita (Hughes-Cromwich et al. 2020). As one of the largest public transportation systems in the United States, the MBTA's multimodal network of buses, subways, ferries, and Commuter Rail lines serve approximately 200 cities and towns and a weekday average of 1.2 million passengers (Massachusetts Bay Transportation Authority 2017; Dickens 2019). The MBTA is responsible for managing an extensive regional transportation network across city lines and responding to customer mobility needs. As one of MassDOT's divisions, the MBTA must also work to advance MassDOT's mission: "to deliver excellent customer service to people traveling in the Commonwealth by providing transportation infrastructure which is safe, reliable, robust and resilient" (Commonwealth of Massachusetts 2020).

3.1.2 Commuting Trends

Approximately 29% of emissions in Boston are transportation-related, almost a quarter of which can be attributed to commutes to and from work (Greenovate City of Boston 2014; MassDOT Planning 2015; City of Boston 2019). Of these commuting trips, SOV rates remain relatively high at 38.9%, compared to those who used alternative forms of transportation, as seen in Table 1 (Boston Transportation Department 2017).

Table 1. Commuting mode split in Boston, 2014.

| Transportation Mode | Commuters |
|----------------------------|------------------|
| Drive Alone | 38.9% |
| Public Transit | 34.0% |
| Walk | 14.3% |
| Carpool | 5.7% |
| Bike | 2.4% |
| Work from home | 3.4% |
| Other | 1.4% |

3.2 Cambridge, MA

Cambridge is internationally recognized as a center for innovation and higher education, with thriving biotechnology and pharmaceutical industries and renowned universities. According to a Bloomberg article published in 2018, “sixty-two public companies with a combined market value of about \$170 billion, the majority of them biotechnology firms, call Cambridge home” (Spalding 2018). Cambridge is also well-known for its famous academic institutions, including Harvard University and the Massachusetts Institute of Technology (MIT), and its large proportion of students, representing just under 30% of the adult population (U.S. Census Bureau 2018b; 2018d).

Cambridge is a highly-educated and relatively wealthy community. Almost half of the residents (48.7%) hold graduate or professional degrees, a value more than double that of Boston (22.1%), Massachusetts (19.1%), and the United States (12.1%) (U.S. Census Bureau 2018b). In addition to high educational attainment, the mean household income is substantially higher for residents of Cambridge (\$130,581), compared to Boston (\$101,310), Massachusetts (\$106,627), and the United States (\$84,903) (U.S. Census Bureau 2018c).

The racial composition of Cambridge residents is more diverse (non-White) than Massachusetts and the United States as a whole, but less diverse than the city of Boston (U.S. Census Bureau 2018d). The majority of Cambridge residents (70.5%) identify as White (US: 75.5%, MA: 81.2%, Boston: 57%) and

12.5% of residents identify as Black or African American (US: 14.4%, MA: 9.2%, Boston: 28.8%), values relatively consistent with the national racial profile. In contrast, 18.1% of residents identify as Asian (US: 6.5%, MA: 7.4%, Boston: 10.7%), a percentage more than double the state- and nation-wide values (U.S. Census Bureau 2018d). In terms of workforce, Cambridge has a higher proportion of employed residents (69.7%), relative to Boston (68.9%), Massachusetts (67.2%), and the United States (63.3%), and nearly half (44.3%) of employed residents work within the City (U.S. Census Bureau 2018c; Cook 2016). 92% commute to nearby cities and towns within the Inner Core of the Boston metropolitan area (Cook 2016; Metropolitan Area Planning Council 2019).

3.2.1 City Sustainability Goals

In addition to Cambridge's knowledge-based economy, the City is also well-recognized for its progressive policies and commitment to sustainability. In 2016 Cambridge was recognized as a 5-Star Community, a national certification system that "allows communities to benchmark their sustainability progress against national standards and their peers" ("Certified STAR Communities" 2016). Cambridge, MA represents one of four communities, out of over 70 certified STAR communities across the country, that has achieved the top certification level. This 5-star rating, also awarded to Northampton, MA, Seattle, WA, and Baltimore, MD, illustrates these communities' commitment to establishing goals, prioritizing policies and programs, and evaluating progress across a range of sustainability themes. Cambridge's recognition as having one of the highest scores is important in acknowledging the City's long-term engagement in advancing community-scale environmental, economic, and social sustainability ("Cambridge Awarded Prestigious 5-STAR Community Rating" 2016).

In Cambridge's most recent comprehensive planning effort, Envision Cambridge (2019), the final report represents a "roadmap to the year 2030, setting out a course of action to promote inclusive and sustainable growth." This document identifies sustainability and resiliency as one of the six core values and incorporates these themes throughout six domains of action - Climate & Environment, Community Wellbeing, Economy, Housing, Mobility, and Urban Form ("Envision Cambridge" 2019). In establishing these priorities, the City ensures that environmental, social, and economic sustainability and resiliency concerns are considered when managing growth and prioritizing development throughout the community.

3.2.2 Municipal Plans and Policies

Support from residents and businesses has helped to nurture and support progressive actions throughout the city. As a result, Cambridge has been able to adopt several initiatives aimed at encouraging environmentally-conscious development and promoting sustainable transportation, as seen in Figure 1.

Timeline of Relevant Transportation Programs, Policies, and Plans

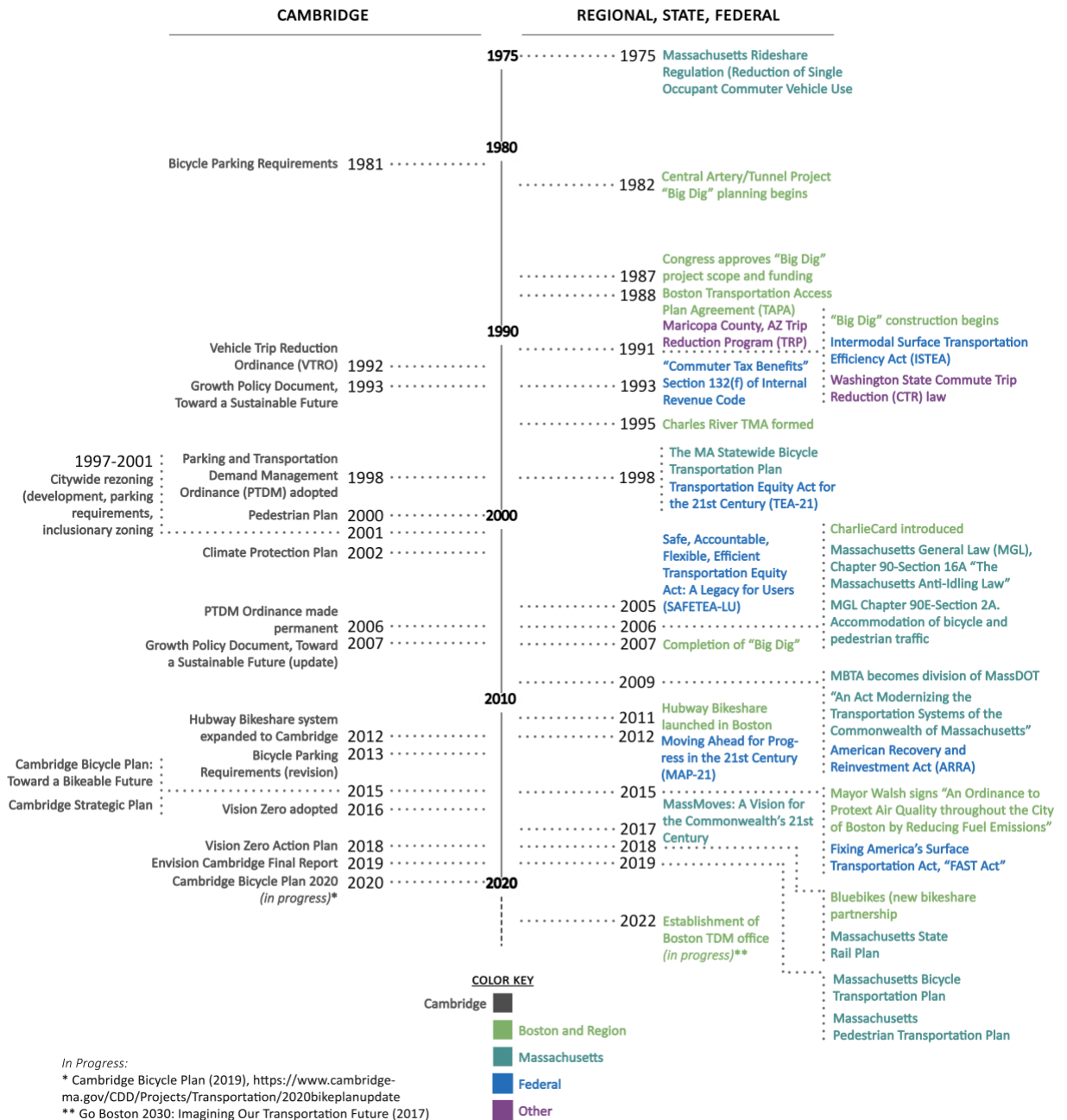


Figure 1. Timeline of transportation-related initiatives at different levels of government.

Cambridge specific programs and policies are represented on the left-side in dark gray text. Regional (green), state (teal), and federal (blue) efforts are represented on the right-side. Influential policies in other cities and counties in the U.S. are shown on the right-side in purple text.

3.2.3 Transportation and Commuting Trends

Cambridge is well integrated into the surrounding metropolitan area transportation system with 32 bus routes and five transit stations located throughout the city, with one station located across the city line in Somerville and plans to add additional stations as part of the Green Line extension project (“City of Cambridge 2015 Transit Strategic Plan” 2018). Based on existing infrastructure, most of the city is considered accessible to transit, or within ¼ mile (10-minute walk)- ½ mile (5-minute walk) of existing rail stations, bus routes, EZ Ride routes, or bike-share stations (“City of Cambridge 2015 Transit Strategic Plan” 2018). Despite the abundance of public transportation options, approximately 8% of transportation-related GHG emissions are attributed to these systems, with the remaining 92% coming from private vehicle usage (Seto et al. 2017). Overall, 11% of all community-wide GHG emissions are attributed to the transportation sector, which includes both passenger and commercial vehicles.

Based on American Community Survey (ACS) 2018 estimates, 25.9% of Cambridge workers drive alone, a low proportion of the population compared to the national average of 76.3% (U.S. Census Bureau 2018a). This is a substantial improvement from 2013, when 45% of Cambridge workers were commuting alone, a figure based on ACS 2011-2013 data (Barr and Rasmussen 2015). When investigating the commuting trends between different groups of workers, commuters traveling within Cambridge show a more sustainable mode split, with higher rates of alternative commuting modes, followed by those commuting from and to Cambridge, as shown in Table 2 (Cook 2016).

Table 2. Commuting mode split in Cambridge.

Data based on the American Community Survey 2006-2010.

| Transportation Mode | Commuting to Cambridge | Commuting from Cambridge | Commuting within Cambridge |
|----------------------------|-------------------------------|---------------------------------|-----------------------------------|
| Drive Alone | 45% | 31% | 16% |
| Public Transit | 26% | 28% | 16% |
| Walk | 13% | 23% | 41% |
| Carpool | 8% | 5% | 4% |
| Bike | 4% | 7% | 9% |
| Work from home | 3% | <1% | 12% |
| Other | 1% | 6% | 1% |

Among those commuting to Cambridge, the percentage of SOV and public transit commuters decreased by 12% and increased by 26% since 1990, respectively (Cook 2016). Following a similar trend for those commuting from Cambridge, the percentage of SOV and public transit commuters decreased by 19% and increased by 20% since 1990, respectively. According to a report published in 2012, travel surveys conducted between 2009-2011 suggest that between 7-9% of Cambridge residents commute to work by bicycle, a range that confirms the estimates from the 2006-2010 ACS data (“By the Numbers: Bicycle Trends in Cambridge” 2012). As a result of these consistent shifts away from driving alone and toward more alternative modes, the values shown in Table 2 are likely conservative estimates of current sustainable transportation behavior.

3.2.4 Kendall Square

Located in Cambridge and adjacent to MIT, Kendall Square has a world-renown reputation as a center for research and a high density of research-focused businesses. Boston Consulting Group described this neighborhood as “the most innovative square mile on the planet,” and the founder and CEO of CIC claimed it as being the “most dense innovation cluster in the world” by (Mingle 2017; O’Connell 2014). This focused growth is largely a result of collaborative redevelopment efforts by the City and MIT (Blanding 2015). Due to the clustering of these technologically-based companies, Kendall Square is also an

innovation district (Katz and Wagner 2014; Storing and Walker 2016; A. Flint 2016). In Kendall Square, companies are invested in maintaining the quality of life amenities that are attractive to employees, including a vibrant, walkable neighborhood. Reflecting these values, many companies have adopted green-commuting benefits - some because they fall within requirements of the VTRO and some who have done so voluntarily (Moskowitz 2012).

In addition to the high density of research and entrepreneurial businesses in Kendall Square, it is located directly across the Charles River from Boston and is well integrated into the metropolitan public transit network. This neighborhood is located on the MBTA's Red Line and serviced by several bus lines (CT2, 64, 68, 85, and the EZRide Shuttle). Based on data collected in 2014, 34% of employees commuting to Kendall Square drive personal vehicles, representing an 8% reduction from 2008 when 42% of workers drove alone ("Transport Kendall Report: Actions to Transform Mobility" 2018). This improvement over time, in combination with the numerous options for alternative transit modes within this neighborhood, will help to further reduce GHG emissions and achieve the City's goal of reducing drive-alone commuters to 30% ("Transport Kendall Report: Actions to Transform Mobility" 2018).

Cambridge's sustainability-focused policies, the large density of progressive employers within Kendall Square, and its proximity to the regional transportation network make this neighborhood an ideal study area for researching the efficacy of employer-provided transit subsidy programs in changing commuting patterns to more sustainable options.

3.3 TransAction Associates

TransAction Associates is a mid-sized, for-profit transportation consulting firm located in the metropolitan Boston area. Founded in 1990 and with approximately 100 employees, this company has grown to provide numerous services within the field of transportation. They work with a range of customers, including non-profits, federal, state, and municipal government agencies, education and research institutions, property managers, and other private companies. Their work includes providing assistance and expertise in the development of transportation management associations (TMAs), the establishment of on-site and off-site transportation coordinator services, the coordination of ridesharing services, and the provision of transportation and commuter planning services. In addition, the company also

operates a fleet of corporate shuttles and shuttle bus systems connecting companies to transit hubs.

Although the majority of their work is with clients in urban settings, they also provide assistance to clients located in rural and suburban environments.

One of their primary areas of work involves partnering with companies and organizations to create transportation solutions through the development of commuter programs and transit route planning. To ensure compliance with municipal and state regulations, they prepare PTDM reports for many sites within Cambridge and Rideshare Regulation Update Reports as required by the Massachusetts Department of Environmental Protection for clients throughout the State. These services have allowed the company to obtain a substantial volume of mode-share data through the distribution and collection of employee surveys. These datasets provide an opportunity to gain an in-depth understanding of incentives that are effective in encouraging commuters to use alternative forms of transportation.

3.4 Context: Defining the Case Study

In summary, the main purpose of this thesis is to understand the ways employer-provided benefits programs influence commuting patterns based on employee survey responses. The results will provide insight into the most effective aspects of commuter benefits and incentive programs which can help inform other area companies interested in creating and adopting similar programs. These findings are placed in the context of the greater geographic region through a comprehensive look at the ways the current policies and plans in Cambridge work to promote and hinder sustainable transportation choices. Looking into specific measures, such as municipal development policies, regulations, and long-term plans, provides insight into the ways that the City influences and shapes the various companies' implementation of commuter benefits. This information further acknowledges the City's role in affecting commuting patterns and their overall impact on urban sustainability.

Together, this case study and larger contextual research are beneficial in informing corporate, regional, municipal, and employee organizations about ways to design and facilitate commuter incentive programs. The findings help to direct the creation and adaptation of policies and regulations that promote shifts in behavior towards more sustainable, alternative transportation choices. In addition, this research helps to identify collaborative opportunities and challenges to initiating a larger-scale commuting shift.

CHAPTER 4 METHODS

This thesis synthesizes commuter survey data, interviews with five organizations working within the Greater Boston transportation sector, and a review of literature ranging from municipal plans and policies to peer-reviewed journal articles. The data analysis combines spatial, quantitative, and qualitative analysis methods.

4.1 Overview of Analysis

This thesis applies three primary methods of data analysis to examine employee survey responses and evaluate commuter behavior patterns including spatial, quantitative, and qualitative analysis (Figure 2). By relating the broader, observed commuting patterns and the reasons influencing employee mode choice, the combination of these methods provides a more holistic understanding of the multidimensional nature of this research topic. Mixed methods research is regarded as a beneficial methodological approach because it allows researchers to gain a fuller perspective of the research question and validate findings through five general purposes: triangulation, complementarity, development, initiation, and expansion (Greene, Caracelli, and Graham 1989). It is used in a range of fields (Fàbregues, Paré, and Meneses 2019), such as health sciences (Regnault, Willgoss, and Barbic 2018) and public health (Pilgrim and Bohnet-Joschko 2019), psychology (Bishop 2015), environmental management (Molina-Azorin 2016), and educational research (Johnson and Onwuegbuzie 2004; Sahin and Öztürk 2019).

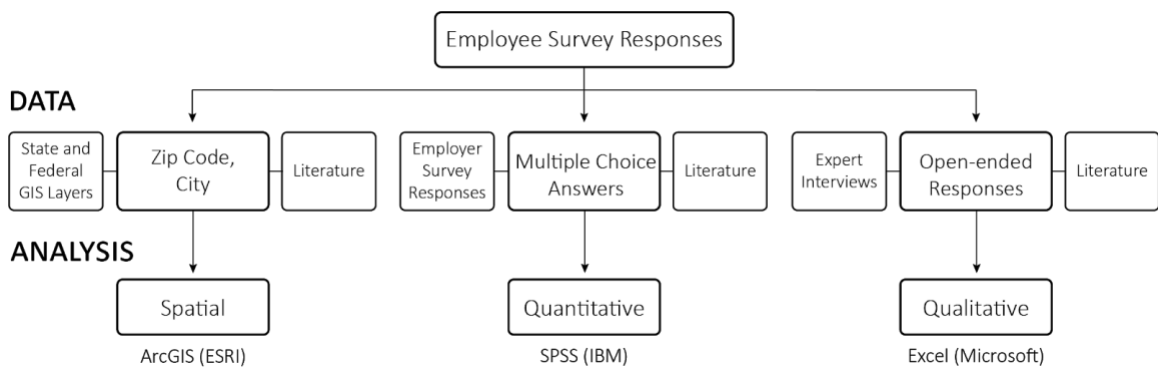


Figure 2. The general workflow of the analysis methods presented in this thesis.

Spatial analysis provides a greater understanding of the ways the study's geographic context influences employee commuting behavior. Quantitative analysis illustrates larger, more general commuting trends at the population-scale through measurable, statistical methods. Qualitative analysis captures the personal, individual-scale attitudes and beliefs of the survey respondents, which provides depth and meaning to the statistical generalizations. All three types of analysis utilize data from the employee and employer survey responses. Information collected from expert interviews supplement the qualitative analysis of survey responses and help to support the discussion section.

4.2 Survey and Interview Data

Every year, TransAction works with companies in the Greater Boston area to better understand commuting patterns among employees. In 2018, TransAction worked with approximately 20 sites in the Greater Boston region and 30 sites in Cambridge. The company administered and collected approximately 15,000 online survey and paper responses within Cambridge, Massachusetts to comply with the City's Parking and Transportation Demand Management (PTDM) Ordinance. TransAction analyzed these data for their clients and prepared 2018 PTDM Annual Report Summaries as required by the City of Cambridge; however, the company has not used the data to understand the influence that commuting benefits have on commuter behavior. TransAction agreed to share these survey data in exchange for the creation of a white paper that they plan to share with clients.

Employees had access to the surveys for one week via the online survey software and questionnaire platform, Key Survey. Employers implemented a variety of outreach methods to notify and recruit employees, ranging from company-wide emails with the survey link to ice cream social events in the lobbies of buildings. In addition, employees who completed the survey were registered for a chance to win prizes, including Apple products (iPads, iWatches) and gift certificates. To supplement the employee survey, TransAction also distributed surveys to employers asking a range of questions regarding their company demographics and an overview of the transportation incentives offered to their employees.

This thesis analyzes a subset of TransAction's larger employee commuter dataset bounded by the geographic region of Kendall Square. The research focuses on this study area because of the large amount of survey data available through TransAction, the high density of businesses in this geographic region, the

relatively large number of accessible public transportation options, and Cambridge's progressive transportation-related policies. Within the sample of companies included in this research, a relatively wide range of employees are represented, including pharmaceutical and biomedical research, higher education, and technology. Despite this variety, it is important to note that the survey responses primarily represent employees within the professional services sector.

Because of the widespread impacts of transportation, this research also incorporates the perspectives of a range of private, public, and nonprofit organizations, all of which are involved in this field of work at differing scales: TransAction, Cambridge's Community Development Department (CDD), the MBTA, Metropolitan Area Planning Council (MAPC), and Kendall Square Association (KSA).

4.3 Spatial Analysis

Spatial analysis of employee survey data establishes broad commuting patterns in relation to respondents' distance to work and access to public transit systems. The results of this analysis have the potential to improve mode split by encouraging attainable shifts in commuting behavior in areas that already have transportation infrastructure in place. In contrast, the results also provide an understanding of transportation network limitations by highlighting underserved areas.

This analysis examines the rate of alternative transportation commuting among employees in transit-accessible locations and identifies areas where transit systems are underutilized by employees. The starting location of employees, in conjunction with the information available about the incentives offered by individual companies, provides valuable data for determining the relationship between location, successful incentive programs, and reduced rates of SOV. Three of the first survey questions asked respondents to provide their origin location – city, state, and zip code. Because zip code data represent the most refined unit of reference attached to the employee survey responses, the spatial analysis in this research relies on studying commuting choices at the zip code scale. Out of the 2,364 survey respondents, 2,353 (99.5%) provided a zip code that corresponded to the city or town that they included. In this research, understanding the distribution of employee origin locations and the spatial component of commuting trends rely on the use of GIS software (ESRI ArcMap 10.7.1 and ArcGIS Online), similar to previous studies

conducted by Panter, Desousa, and Ogilvie (2013), Panter et al. (2013), Panter et al. (2016), and Chakrabarti (2017).

The application of GIS spatial and network analysis tools illustrates the areas where commuters underutilize transit, by comparing the amount of transit-accessible land to employee SOV and alternative commuting rates. This analysis examines three alternative transportation modes - buses, the T (light rail), and the commuter rail (heavy rail). Based on spatial data (source information available in Appendix A) and the street network layer (ArcGIS Online), the generated walksheds around transit stations throughout the region illustrate the areas from which transit is most accessible to pedestrians (Figure 3).

Because the MassGIS layer for the bus routes and stops encompasses a large network spanning the state, this research focuses on a more geographically refined walkshed analysis that includes the stops located in MAPC's 21 Inner Core Communities. Because of the denser and more consistent bus network within Boston, the use of bus stops in these 21 towns and cities is an attempt to address an overestimate of bus use in areas with less convenient and less reliable service. To capture daily train commuter behavior, walksheds surrounding commuter rail stations operating throughout the year are the main focus of this analysis, thus, eliminating the need to incorporate stations classified as "seasonal commuter rail service," which MassGIS defines as for summer service to Cape Cod (Wareham, Buzzards Bay, Hyannis) or special events to Gillette Stadium (Foxboro).

According to research published by the Federal Highway Administration, the majority of people are willing to walk $\frac{1}{4}$ to $\frac{1}{2}$ mile to a transit stop and farther distances when accessing heavy-rail services (Nabors et al. 2008). The analysis in this thesis applies a walkshed of $\frac{1}{4}$ mile toward the T stations and bus stops, and a walkshed of $\frac{1}{2}$ mile toward commuter rail stations, both of which represent conservative walking distances based on generally accepted commuter behavior (an example of this process is shown in Figure 3a). This method used to approximate transit access and the influence of the built environment is similar to research conducted by Ye (2017) in Xi'an, China. To understand the interaction between origin locations, transit accessibility, and transit use, this analysis combines the bus, T, and commuter rail walksheds to identify transit-accessible areas (an example of this process is shown in Figure 3b). Because the smallest unit of measurement for employee origin provided through the survey was zip code, this

research focuses on the zip codes that are at least partially intersecting the combined transit walkshed (an example of this process is shown in Figure 3c).

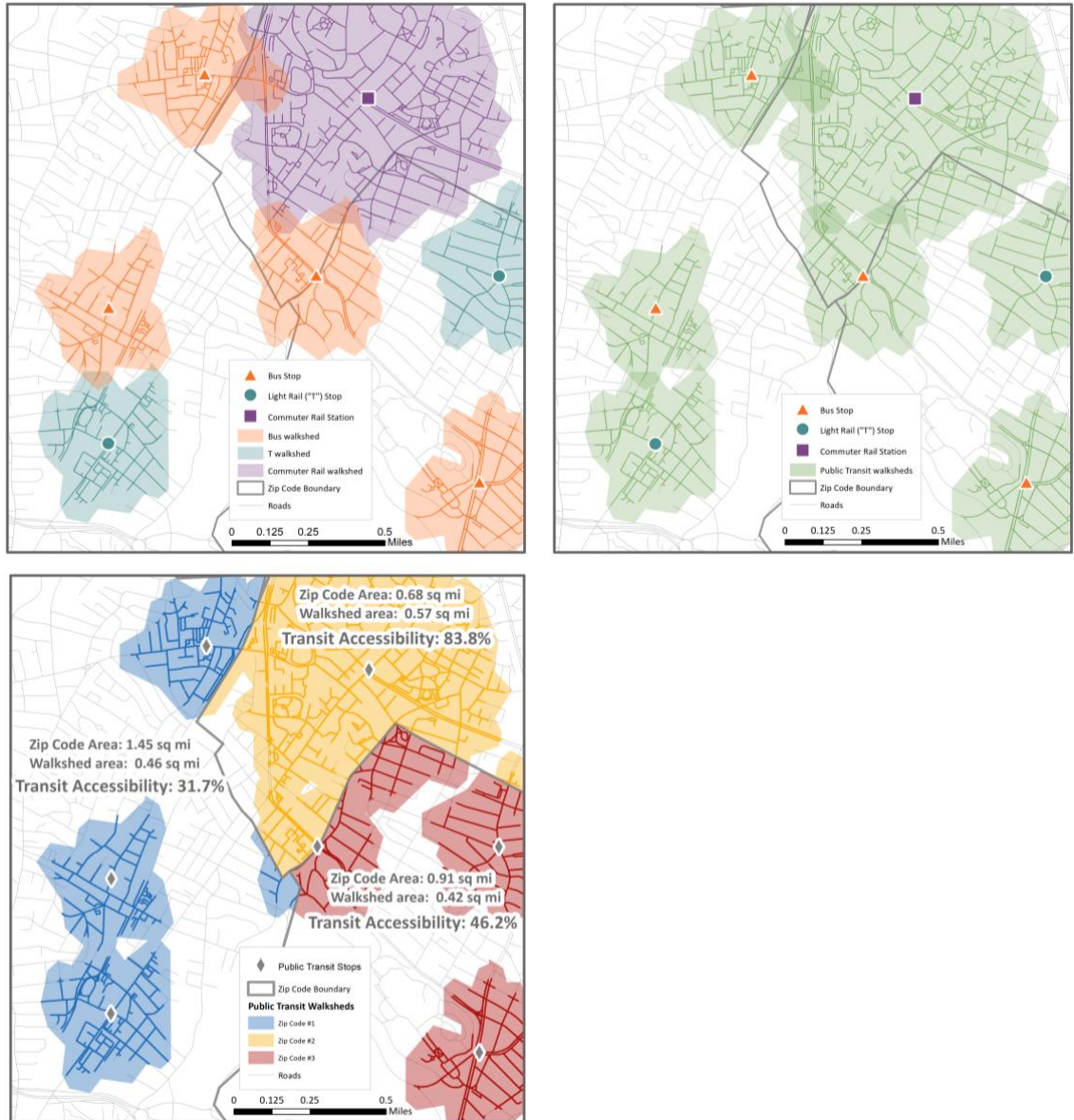


Figure 3. Visualization of walkshed generation and spatial analysis.

Figure 3a (top left). Walksheds of ¼-mile are generated around bus stops (orange) and T stations (teal). Walksheds of ½-mile are generated around commuter rail stations (purple). **Figure 3b** (top right). All public transit walksheds are combined to reflect overall transit-accessible areas. **Figure 3c** (lower left). Transit accessibility is calculated at the zip code scale. In this example, the transit walksheds are categorized by the zip codes in which they are found.

Calculating the proportion of area accessible to transit relative to the total zip code area is an analytical attempt to limit overestimation. Establishing a threshold of 25% or greater transit accessibility

narrows the focus of this analysis on the zip codes with the highest potential for mode shifts by disregarding the zip codes that are categorized as having low accessibility. To limit distortion and ensure that employee numbers are fairly representative of commuting behavior within zip codes, a concern identified by Martin (1997), this analysis focuses on zip codes within the upper quartile of number of respondents.

4.3.1 Limitations

This method represents an analytical attempt to spatially consider the scale of the available survey data and existing transit infrastructure. Because of the limitations of the analysis methods and reliance on several assumptions, the findings from this analysis should be interpreted with caution.

The first major assumption on which this analysis relies is that employees are distributed equally throughout their origin zip codes. Although land use, zoning, and residential density are important factors when determining access to transit, they are not integrated into this analysis, unlike the analysis conducted by Su and Zhou (2012). Another limitation is the variation in zip code size. Because rural zip codes cover larger areas, they are less accurate than the zip codes in more urban areas, which cover less area and where land use is more likely to be homogenous and integrated. This analysis oversimplifies spatial patterns, which introduces the potential for misrepresentation.

The second set of limitations involve the use of walksheds to represent accessibility. Although ArcGIS generates walksheds that “follow paths and roads that allow pedestrian traffic and...optimize travel distance,” this analysis tool does not take into account the experiential quality of the surrounding environment (ArcGIS Online). The topography, streetscapes and landscaping, traffic volume and speed, and the quality of sidewalks and roads all impact the willingness of pedestrians to travel farther or shorter distances along routes (Ewing 1999). Despite the influence of the built environment on commuter behavior, this analysis assumes that all roads or paths that allow for pedestrian traffic are comparable in terms of safety and comfort.

Lastly, this analysis combines the three transit types to distinguish between transit-accessible and inaccessible areas. This relies on the assumption that all three types of alternative transportation are equally

accessible and attractive to commuters. In reality, many factors may impact an individual's choice to use a specific mode. For example, although an individual is within ¼ mile of a bus stop, the bus route may not be well serviced or may require multiple transfers which could affect commute behavior. As a result of these limitations, the results of this simplified, multi-scalar analysis are intended to represent a general approximation of spatial trends, rather than establish direct associations.

4.4 Quantitative Analysis

Quantitative data analysis of employee survey responses contributes a broader, more general understanding of the ways employer-provided commuting incentives influence employee commuting behavior. Survey respondents completed a travel diary for one designated week between April and June (2015-2018), by choosing from 18 commuting mode options for each day of the week (Appendix B). Corresponding employers completed a survey indicating the types of incentives that they provide for their employees (Appendix C). Out of the 2,364 survey responses, 19 respondents did not provide their employer and are not considered in this analysis. Despite these incomplete responses, this analysis accounts for 99.2% of total employee responses.

This analysis generates individual mode split values by counting the number of times each survey respondent reported using a specific commuting mode during the week. Categorizing some of the 18 pre-selected commuting choices into three main categories simplifies employee responses to reflect their primary modes (Figure 4). As defined by the City of Cambridge, SOV commuting includes employees who choose to “take a ride-hail service, such as Uber, Lyft, or taxi, as a solo passenger” (Farooq and DePasquale, 2019). It is important to note that there is some overlap between the main categories of interest, depending on the commute mode (e.g. the pre-selected commuting choice “public transit and walked” corresponds to three categories: “public transit” and “active transportation” and “public transit or active transportation”). Therefore, the different commuting categories are not mutually exclusive and must be analyzed separately to avoid misinterpretation. Correlating the individual mode split values with the presence or absence of employer-provided incentives illustrates the association between benefit and behavior, with special attention given to the three benefits corresponding between the employee and employer survey (Appendix D). SPSS (IBM, Version 25) and Excel (Microsoft Office 365, Version 16.0)

software are the primary programs for conducting quantitative analysis and determining statistical significance.

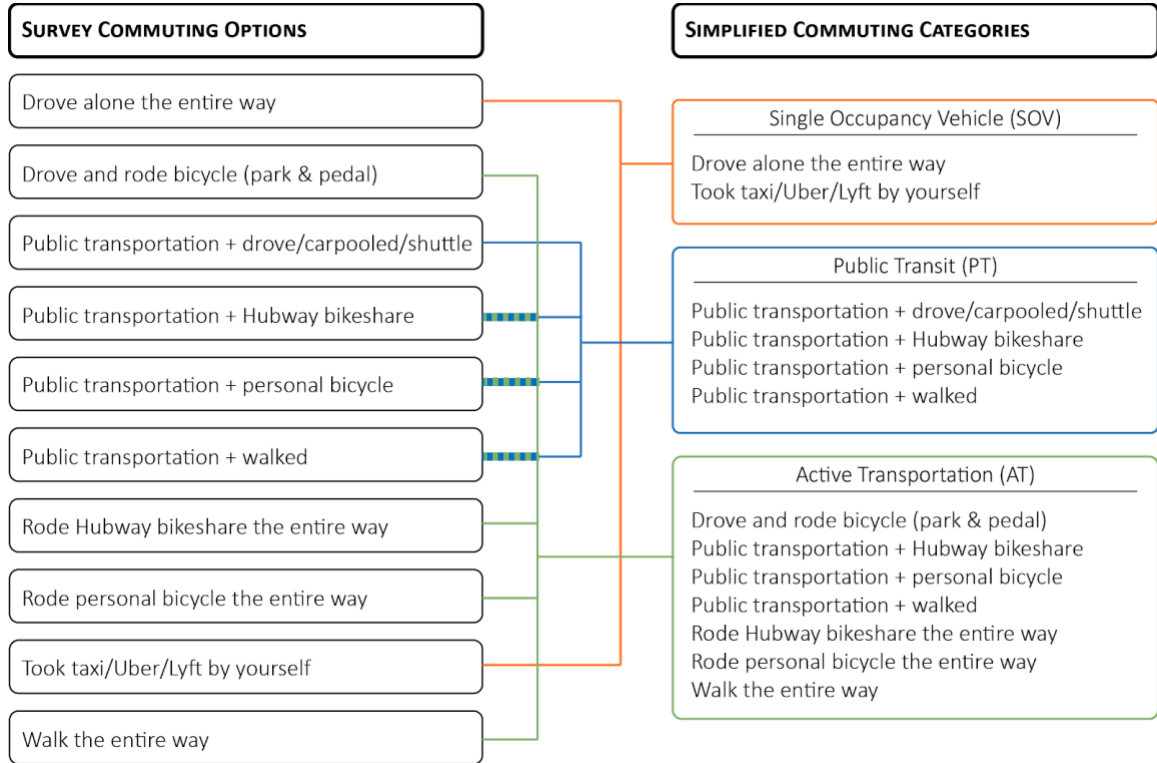


Figure 4. Original survey choices organized into simplified commuting categories.

The TransAction survey provided respondents with 18 survey commuting options to reflect their day-to-day commute. For analysis, these commuting choices are organized into three broader commuting categories, reflected by the column to the right. The dashed blue and green lines indicate that these survey commuting options qualify as both “Public Transit (PT)” and “Active Transportation (AT)” commuting categories.

4.4.1 Statistical Tests

The application of one-way ANOVA tests establishes the presence, absence, and strength of the relationship between employee commuting behavior and the provision of subsidies and incentives (Eriksson, Nordlund, and Garvill 2010; Panter et al. 2013; Tajalli and Hajbabaie 2017). The independent variables in these analyses are the employer-provided incentives and the dependent variable is employee mode split rate. For these analyses, two groups of respondents emerge: 1) employees working for companies that provide the incentive; 2) employees working for companies that do not provide incentives.

When assessing the association between employer-provided incentive and employee commuting behavior, the threshold for statistical significance is an alpha level of 0.05.

ANOVAs test for significant differences between the means of two or more groups; however, they rely on the assumption that the population variances of the groups being compared are equal. If this assumption (Levene's test) is violated and unequal variance is present, findings could result in Type I errors (false rejection of the null hypothesis). When variances between populations are unequal in this research, the application of Welch ANOVA tests provides an alternative analysis method (Ulvi et al. 2019). The benefit of the Welch ANOVA is its ability to report a reliable confidence interval when comparing means of unequal variance (Wilcox 1989; Grissom 2000; Delacre et al. 2019). In this study, using Welch ANOVA tests provide a statistically valid method to analyze the way different incentives may have influenced mode choice among survey respondents.

After an ANOVA analyzes the interaction between three or more groups and reveals a significant relationship, post-hoc tests provide a method to better understand the way these different test groups interact, by identifying where the relationships are significant. Based on the Welch ANOVA, the Games-Howell post hoc test was designed to account for unequal variance between analysis groups (Shingala and Rajyaguru 2015; S. Lee and Lee 2018). While Tukey's Honest Significant Difference (HSD) post hoc test is one of the most commonly used methods to compare specific groups, it relies on the assumption of equal variances, similar to the standard ANOVA. Therefore, when the assumption of equal variances or equal sample sizes is violated in this analysis, the Games-Howell post hoc test provides a valid alternative to the commonly used Tukey HSD (Sauder 2017; S. Lee and Lee 2018). The eta squared values (η^2) provide an additional value to measure the strength of the association between the dependent and independent variables of interest.

Similar to the one-way ANOVA, a univariate General Linear Model (GLM) tests for an interaction between the employer-provided incentives and employee mode choice; however, it allows for the input of multiple independent variables. The application of the heteroskedasticity-consistent standard

error estimator (HC31) provides a reliable correction method to account for non-homogeneity of variance because it exhibits the “least size distortion” (Muhammad 2014). The application of heteroskedasticity-consistent standard error estimators is an established method to correct for homogeneity of variance and to ensure the validity and power of linear regression models (Hayes and Cai 2007; Cribari-Neto and da Gloria A. Lima 2014; Long and Ervin 2000).

4.4.2 Limitations

When analyzing employee responses, there are common limitations associated with large, general datasets, mainly due to the nature of the data and the way it was collected. While the majority of the survey responses used in this analysis are from employees at 14 companies during one week in April or May 2018, data from two companies that completed their surveys in April 2017 and data from one company surveyed in June 2015 are also considered. The employees at these three outlier companies represent 12% of the total responses. The use of these data presents a limitation because of the different months and years during which the data was collected. In the Northeast, the difference between mid-April and late May presents one challenge of combining these survey responses due to the seasonal differences in temperature and weather conditions. Weather conditions affect commuting mode choice (Böcker, Dijst, and Prillwitz 2013), especially for those who may commute by alternative transportation modes, such as bicycling (Heinen, Maat, and van Wee 2011; Ahmed, Rose, and Jakob 2013) and public transit (Guo, Wilson, and Rahbee 2007; Tang and Thakuriah 2012; Arana, Cabezudo, and Peñalba 2014). In addition to the month differences, two companies completed their surveys in 2017 and one in 2015. Due to changing infrastructure, route schedules, traffic patterns, and evolving social attitudes, the three-year difference in survey responses presents an additional challenge when attempting to determine the factors that impact employee commuting choices.

¹ HC3 can “keep the test size at the nominal level regardless of the presence or absence of heteroskedasticity (and there is only a slight loss of power associated with HC3 when errors are indeed homoskedastic)” (Hayes, 2007).

The responses to the survey were self-reported, a data collection mode which includes a degree of error due to response bias (Stone 2000; Donaldson and Grant-Vallone 2002) and a tendency for respondents' attitudes and beliefs to be influenced by the research context and format (Schwarz 1999). The purpose of this annual survey is to understand employees' commuting behavior. Although traffic is not a unique issue to Boston, it has been well documented and publicized within the past few years, resulting in increased attention and widespread efforts to reduce commute-related congestion and the environmental consequences associated with SOVs. As a result of the way this survey was framed, the employees who responded may have been influenced to believe that it is more socially acceptable to choose commuting modes that are alternatives to driving alone, especially for those who identify as environmentally conscious. Although participants' responses are anonymous, they may have emphasized certain aspects of their commute in response to the phrasing of questions.

Another major limitation of the survey data is the lack of demographic information attached to the survey responses. While the employee survey asked respondents to provide their origin city and zip code, no other identifying information was collected. Demographic data helps to verify that the survey respondents are representative of the larger population. Without this information, it is difficult to determine whether the individuals working at these companies and responding to these surveys reflect the general commuting behavior trends of the region or remain a subset of the population.

Lastly, as Su and Zhou (2012) indicate in their research into commuter mode choices in Seattle, the survey variables are limited by the availability of data. While these large datasets can provide a relatively reliable understanding of general commuting patterns within these urban centers, the results represent an approximation of patterns because of lack of detailed data, such as vehicle information and more precise origin locations - streets or closest intersections. Therefore, the findings presented in this research establish associations and relationships between the variables, rather than causalities.

4.5 Qualitative Analysis

4.5.1 Surveys

Qualitative data analysis of employee survey responses contributes to this research by establishing the personal factors impacting employee commuting choices. As part of the survey, participants were

prompted to consider the reasons for choosing to commute using the mode that they reported in their travel diary (refer to section 4.4 Quantitative Analysis; Appendix B). Respondents were provided with a variety of pre-selected answer choices and asked to check all that applied. Following these questions, employees had the opportunity to provide open-ended responses explaining their choices and reasoning. This research incorporates manifest content analysis to investigate the open-ended responses, identify common themes, and quantify the prevalence of similar, main ideas (Bengtsson 2016; Waitt 2016).

- **Question: “What are your reasons for driving alone?”**

The employee survey provided respondents with 17 pre-selected options to account for their choice to drive alone to work (Appendix B). They were asked to select all that applied to their personal commuting situation. In addition, respondents had an opportunity to provide an open response “other” option.

- **Question: “If you walk/bike/take transit/carpool, why?”**

The employee survey provided respondents with 14 pre-selected options to explain their use of alternative commuting modes (Appendix B). They were asked to select all that applied to their personal commuting situation. In addition, respondents had an opportunity to provide an open response “other” option.

- **Question: “What would cause you to switch from driving alone to another mode of transportation?”**

The employee survey provided respondents with 15 pre-selected options for possible incentives that could encourage them to switch from driving alone to taking an alternative mode of transportation (Appendix B). They were asked to choose one of three responses (“not likely,” “somewhat likely,” and “very likely”) when presented with each of the pre-selected potential incentives. In addition, respondents had an opportunity to provide an open response “other” option.

4.5.2 Interviews

Supplemental semi-structured interviews with representatives of five local organizations provide an opportunity to further contextualize this research as part of the ongoing efforts to improve the region’s transportation trends. As explained by Dunn (2016), the flexible nature of semi-structured interviews provides the informant with the opportunity to discuss their area of work while being guided by subjects relevant to the research question.

Phone calls and email exchanges with staff members helped to initiate contact and coordinate interviews for February and March 2020. Contacts received general questions and discussion topics one-two weeks in advance of the conversations.

TransAction Associates is a company within the private sector, the CDD, MBTA, and MAPC are government agencies, and the KSA is a nonprofit, all involved in transportation-related work in the region.

- TransAction Associates works closely with their clients to offer transportation consulting services to “companies subject to commuter-related compliance reporting requirements and all transportation

demand issues.” Although TransAction is largely dependent on taking into account the existing system and regulations, they also must consider continually evolving transportation innovations. Because of their many connections throughout the region, they also have the potential to exert influence on public policy and their clients' transportation patterns.

- The MBTA is the public agency responsible for providing and operating a wide range of public transportation options in the Greater Boston region. As part of the Massachusetts Department of Transportation (MassDOT), this agency is the fourth-largest transit agency in the country, operating rapid transit, commuter rail, bus and trolley routes, paratransit services, ferries, and park and ride lots (Hughes-Cromwich, 2019).
- MAPC is the regional planning agency responsible for providing support to the 101 communities considered to be within the metropolitan Boston region. Because of the many departments within the organization, the broad mission includes promoting “sound municipal management, sustainable land use, protection of natural resources, efficient and affordable transportation, a diverse housing stock, public safety, economic development, clean energy, healthy communities, an informed public, and equity and opportunity among people of all backgrounds.” As the public agency responsible for regional collaboration, the transportation department is closely involved in coordinating comprehensive and complementary sustainable mobility options for those living and working in the area.
- The CDD acts as the planning agency for Cambridge, with five main collaborative programmatic divisions (Community Planning, Housing, Economic Development, Environmental and Transportation Planning and Zoning and Development). The overall mission of the department is to “enhance the character and diversity of the city’s neighborhoods and support sustainable economic growth that expands opportunities for residents, enables a high quality of life within the community, and contributes to a healthy environment.” The CDD creates, implements, and enforces policies to benefit residents and advance the goals set by the City.
- KSA, an organization consisting of local business and community leaders, advocates for the continued health and vibrancy of the Kendall Square neighborhood through programming, research, and the facilitation of professional partnerships.

Speaking with individuals from these five organizations illustrates the interdependent efforts being made to promote sustainable and efficient transportation to individuals living and working in the Greater Boston region. In addition to providing insight into the ways that these organizations interact and work together to adapt their strategies, these interviews help to identify strengths and challenges of the partnerships among the stakeholders working within this realm. Using the information gained from these interviews, coding (Cope 2016; Crang 1997) and latent content analysis (Bengtsson 2016; Dunn 2016) provide quantitative methods to distill key themes. Comparing the responses across interviews provides a better understanding of the areas for improvement that could further advance the interconnected missions and goals of these organizations.

4.5.3 Limitations

One of the main limitations of the survey data used in this analysis is the lack of correspondence between the employer survey and the survey completed by employees. Employees were asked if they are aware of being provided with 10 common PTDM-related incentives; however, only three of these correspond to the incentives asked of the employers. As a result, investigating these three incentives when looking at employee mode split across companies was especially important to determine the relationships between incentive, awareness, and behavior (Tables 6 and 7). In addition to the three incentives asked of employers, one open-ended response option asked for a list of any additional incentives or benefits that they provided to their employees (Appendix C). They were prompted to list incentives offered to “help promote the use of transit, carpooling, biking and walking.” Eight of the 17 companies completed this section, limiting the reliability of these data when analyzing the impact of these additional incentives on the commuting behavior due to the smaller respondent populations.

As with all research methods, subjective interpretation of the data must be acknowledged (Winchester and Rofe 2016; Bourke 2014; Malterud 2001; Hopkins 2007). Although many consider quantitative analysis methods to be more objective than qualitative methods, the larger context of this research and personal subjectivity inherently influence both types of analysis through the research question, the categorization of variables, the interpretation of open-ended responses, and the structure of the statistical tests applied to determine significance.

As the researcher, my cultural background, and positionality are important to acknowledge as having a role in the development and framing of this thesis. My identity and privilege as an upper-middle-class, non-disabled female growing up in a suburb of Boston and attending college at a small liberal arts college in Vermont provided me with access to social and financial capital. Pursuing a dual degree in geography and regional planning, disciplines that are historically predominantly white fields of research, also led to interactions and experiences which have further shaped my personal identity and worldview. Thus, the political, social, economic, historic, and educational factors that have contributed to my academic and personal experiences greatly influence the research topic and design, narrative perspective, and the assumptions made throughout this project.

CHAPTER 5 RESULTS

A total of 2,364 participants responded to the survey, with over 98% (2,330) providing complete responses (company, city, and zip code). Employee response rates by employer varied between 10% to 100%, with an average rate of 59%. Figure 5 and Table 3 present descriptive statistics regarding respondent characteristics and company statistics, respectively.

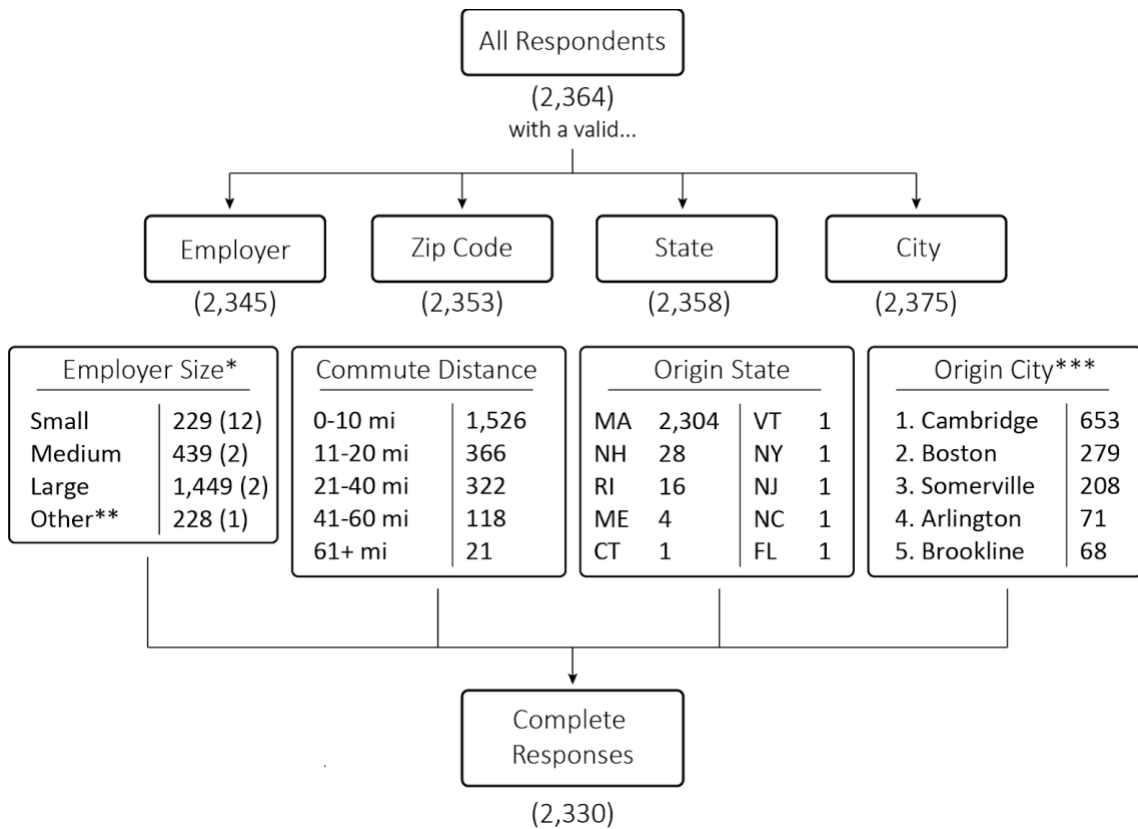


Figure 5. Summary characteristics of employees included in this research.

* Values reflect the number of survey respondents that reported working at companies classified as small (1-100), medium (101-500), large (500+), based on the total number of employees that each company indicated in their employer survey. The values in the parentheses reflect the number of companies within each size category.

** One company did not provide the total number of employees in their employer survey and could not be classified based on size.

*** The five cities listed were the most frequently mentioned when the TransAction survey asked respondents to provide the city from which they began their commutes. Respondents provided a total of 204 cities and towns in the employer survey.

Table 3. Summary characteristics of employers included in this research.

| Employer Information | | | Employer-provided Benefits | | | Employee Commuting Behavior ¹ | | |
|----------------------|------------------------------|---------------|----------------------------|--------------------|-----------------------|--|------|------|
| Company | Size of Company ² | Response Rate | Free Parking | Subsidized Transit | Information Available | SOV | PT | AT |
| 1 | Large | 61% | No | No | Yes | LOW | MID | HIGH |
| 2 | Medium | 70% | No | Yes | Yes | HIGH | MID | HIGH |
| 3 | Small | 48% | Yes | Yes | No | HIGH | LOW | HIGH |
| 4* | N/A | N/A | Yes | No | Yes | HIGH | LOW | LOW |
| 5 | Small | 100% | No | Yes | No | LOW | HIGH | HIGH |
| 6 | Small | 43% | Yes | Yes | No | MID | MID | HIGH |
| 7** | Small | 80% | N/A | No | No | MID | HIGH | HIGH |
| 8 | Small | 10% | Yes | No | No | MID | LOW | LOW |
| 9 | Small | 63% | Yes | Yes | No | HIGH | LOW | LOW |
| 10 | Small | 48% | Yes | Yes | No | MID | HIGH | LOW |
| 11 | Small | 66% | N/A | N/A | N/A | MID | LOW | LOW |
| 12 | Small | 61% | No | Yes | Yes | HIGH | MID | HIGH |
| 13 | Small | 64% | No | Yes | No | LOW | HIGH | HIGH |
| 14 | Small | 75% | Yes | Yes | No | LOW | HIGH | HIGH |
| 15 | Large | 79% | Yes | Yes | No | HIGH | LOW | LOW |
| 16 | Small | 15% | No | Yes | No | MID | HIGH | HIGH |
| 17 | Medium | 63% | No | Yes | No | LOW | MID | HIGH |

*Number of employees in 2018 unknown

**Majority of employees do not sit in the office

¹ Average SOV (Single Occupancy Vehicle), PT (Public Transit), AT (Active Transportation) commuting rates categorized into three groups (Low, Mid, High) based on the two calculated tertiles

² Small (1-100 employees), Medium (101-500 employees), Large (more than 500 employees)

5.1 Theme 1: Free Parking and SOV Commuting

Homogeneity of variance among employee SOV rates (commuting days/week) at companies that provide free parking and those that do not is violated, *Levene's test* $F(1, 2317)=68.97, p<0.001$; thus requiring the use of Welch's test to determine significant differences. There is a significantly higher rate of SOV commuting among employees at companies that provide free parking in comparison to employees at companies that do not, *Welch's F* $F(1, 454.93)=63.85, p<0.001$ (Table 4). Based on this result, the choice to drive alone differs significantly between those who are provided with free parking and those who are not, with the average rate of SOV travel increasing by about 86.84% between the former (2.13 average SOV commuting days/week) and latter groups (1.14 SOV commuting days/week).

The eta squared ($\eta^2=0.03$), a value representing the effect size, indicates that approximately 3% of the total variation in SOV rates can be attributed to differences in the employer-provision of parking. While the effect size may seem relatively small, a common occurrence in behavioral science, it represents a relationship that falls within the small-medium benchmark ranges, as defined by Cohen (1988).

Table 4. Average SOV commuting (days/week) based on commute distance.

SOV rates are significantly higher when free parking is provided to employees. There are statistically significant relationships between free parking and SOV commuting rates for employees reporting commutes less than 10 miles and greater than 10 miles.

| Distance | Average SOV Commuting (days/week) | | ANOVA | | |
|---------------------------------|-----------------------------------|-----------------|--------------|--------------------------|-------------------------------|
| | Free Parking | No Free Parking | Significance | Eta squared (η^2) | Effect benchmark ₁ |
| All ₂ | 2.13 | 1.14 | ** $p<0.001$ | 0.032 | Small-medium |
| Less than 10 miles ₂ | 1.94 | 0.81 | ** $p<0.001$ | 0.042 | Small-medium |
| Greater than 10 miles | 2.34 | 1.81 | * $p=0.005$ | 0.010 | Small |

* $p < 0.05$; ** $p < 0.001$

₁ Benchmark effect size: small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), and large ($\eta^2 = 0.14$) (Cohen 1988)

₂ Welch ANOVA

This analysis applies a univariate GLM and the HC3 estimator to test the relationship between free parking and subsidized transit on SOV commuting, with distance as a covariate. When employees are provided with free parking and transit subsidies, the most influential variable is parking (Figure 6). The

provision of free parking results in significantly increased rates of SOV commuting [$t(1) = -4.042$, $p < 0.001$], while the provision of subsidized transit and distance are not statistically significant at the 0.05 level.

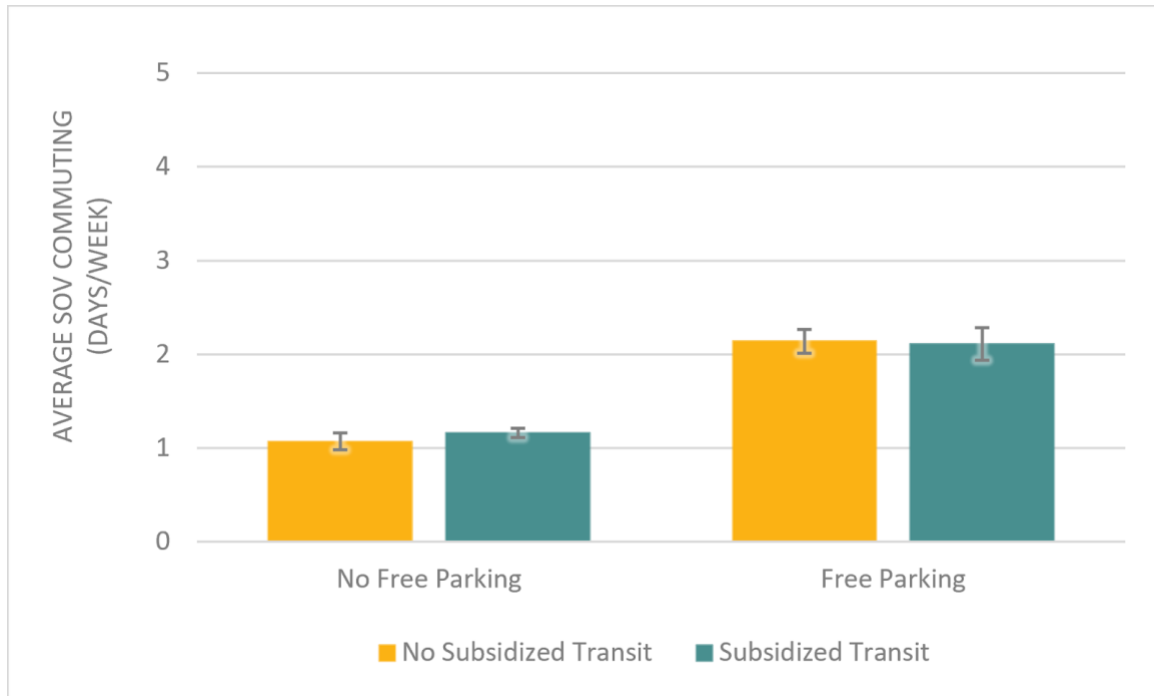


Figure 6. Average SOV commuting based on the provision of free parking and subsidized transit.

Employees who are provided with free parking commute by SOV at significantly higher rates than employees who must pay for parking. The y-axis values reflect the average number of times/week participants commute by SOV. The provision of subsidized transit (teal) does not significantly reduce the rate of SOV commuting. Covariates appearing in the model are evaluated at the following values: Distance = 1.64. Error bars: 95% CI.

For employees commuting 10 or fewer miles one-way, homogeneity of variance among employee SOV rates for those who are provided with free parking and those who are not is violated, *Levene's test* $F(1,1488)=89.43$, $p < 0.001$; thus requiring the use of Welch's test. The SOV rates of employees commuting less than 10 miles one-way are significantly higher (140%) when free parking is provided, *Welch's F* $F(1, 454.93)=63.85$, $p < 0.001$. Similarly, the provision of parking for employees beginning their commutes farther than 10 miles from their work location significantly increases (29%) SOV commuting rates, $F(1, 816) = 8.075$, $p = .005$. While free parking significantly increases the rate of SOV commuting in both distance groups, parking has a larger effect on those commuting from locations that are less than 10 miles

from their work locations ($\eta^2=0.042$) than employees commuting from distances farther than 10 miles ($\eta^2=0.010$).

When employees were asked about their reasons for choosing to commute by SOV, 82.2% (1,944) of respondents chose at least one of the 17 pre-selected options (mean = 2.4, median = 1). From the pre-selected options, the reasons that received the highest response rates were “Take children to school, daycare or activities” (32.1%), “Most convenient way to commute” (27.1%), “Errands before/after work” (25.3%), and “Fastest way to commute” (21.8%), as shown in Figure 7. A full list of the ranked choices is available in Appendix D.

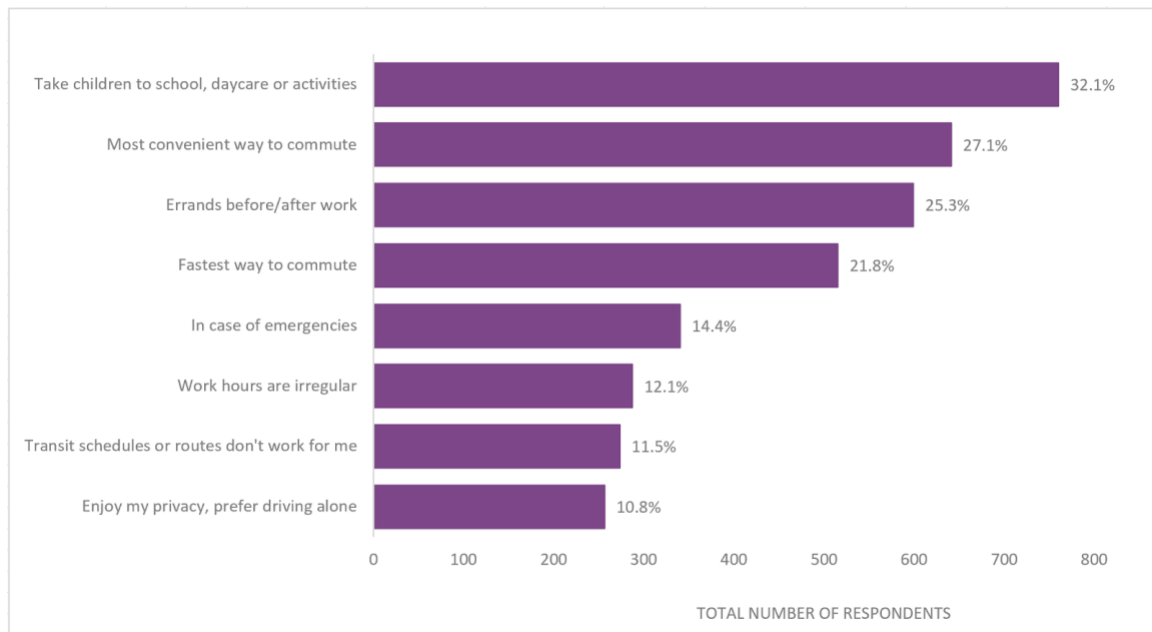


Figure 7. The most frequently chosen reasons for commuting by SOV.

The options shown above represent a subset of the total 17 choices provided within the survey (Appendix B). The percentage values reflect the proportion of the total number of survey respondents (2,364) who chose each reason.

Of the 3.7% (87) of survey respondents who provided additional open-ended responses, the majority of reasons are personal or related to transit limitations. The reasons categorized as personal can be further organized into reasons that are at a smaller, more individual scale to those that are due to larger-scale reasons that could be addressed by employers or policy makers. These personal reasons also range from the more inflexible or difficult to change, such as disabilities or injuries, to easier, more flexible changes, such as familiarity and awareness. Pre- and post-work activities and work schedules and work responsibilities were the most frequently mentioned personal reasons while unreliability and inadequate infrastructure were

the most frequently mentioned transit-related reasons, as shown in Figure 8. More detail about the categorization process is in Appendix D.

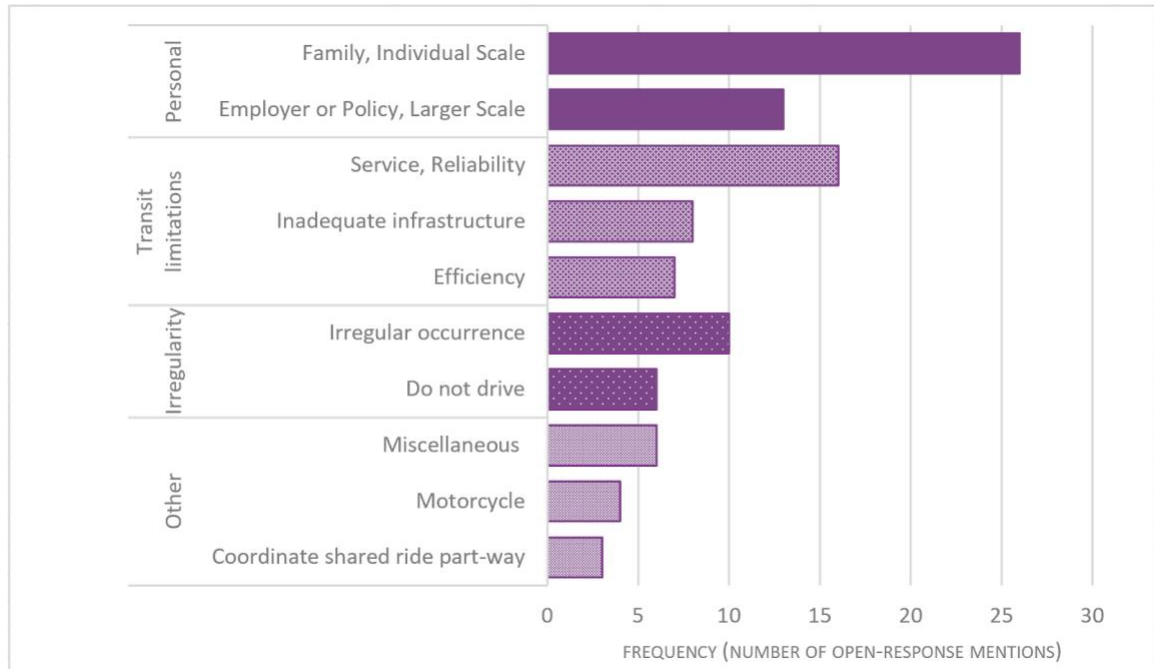


Figure 8. Open-ended responses for choosing to commute by SOV.

When prompted by the question, “What are your reasons for driving alone?” 87 participants provided 95 reasons. The more specific responses (right) are organized into broader themes (left), organized from most frequently mentioned to least frequently mentioned, within each theme.

5.2 Theme 2: Alternative Modes of Transportation

5.2.1 Transit Subsidies

Homogeneity of variance among employee public transit rates at companies that provide transit subsidies and those that do not is violated, *Levene’s test* $F(1, 2325)=27.35, p<0.001$; thus requiring the use of Welch’s test. The results indicate that employees working at companies that provide transit subsidies utilize public transit at significantly higher rates, *Welch’s F* $(1, 1395.04)=13.98, p<0.001$. The rate of commuting by public transit increased by 19.47% with the provision of transit subsidies. The eta squared ($\eta^2=0.01$) indicates that approximately 1% of the total variation in SOV rates can be attributed to differences in the employer-provision of parking. Although modest, this small effect size has meaningful implications for reducing barriers and promoting more sustainable mode splits (Cohen, 1988).

5.2.2 Transit Accessibility

Respondents reported beginning their commutes from 281 different zip codes, representing 10 states - Massachusetts, New Hampshire, Rhode Island, Maine, Vermont, Connecticut, New York, New Jersey, North Carolina, and Florida, as shown in Figure 9a. Figure 9b displays the distribution of 266 valid origin zip codes of participants within the New England states. Of the valid zip codes reported by survey participants, 66.2% (176) are accessible to some form of public transit based on walkshed analysis (Figure 9c).

As the percentage of the land area accessible to transit increases, public transit use steadily increases (Table 5). This result corresponds to decreasing rates of SOV commuting as transit accessibility increases. Of the 1,538 respondents who reported starting their commutes from one of the 75 zip codes that are at least 25% accessible to transit, an average of 25.1% (252) reported driving alone 4 or 5 times a week. In comparison, 28.8% (525) of all respondents with a valid zip code (2,353) reported driving alone 4 or 5 times a week. Although this difference is relatively minor, these results illustrate that transit accessibility is one of the many considerations that impacts commuting mode choice.

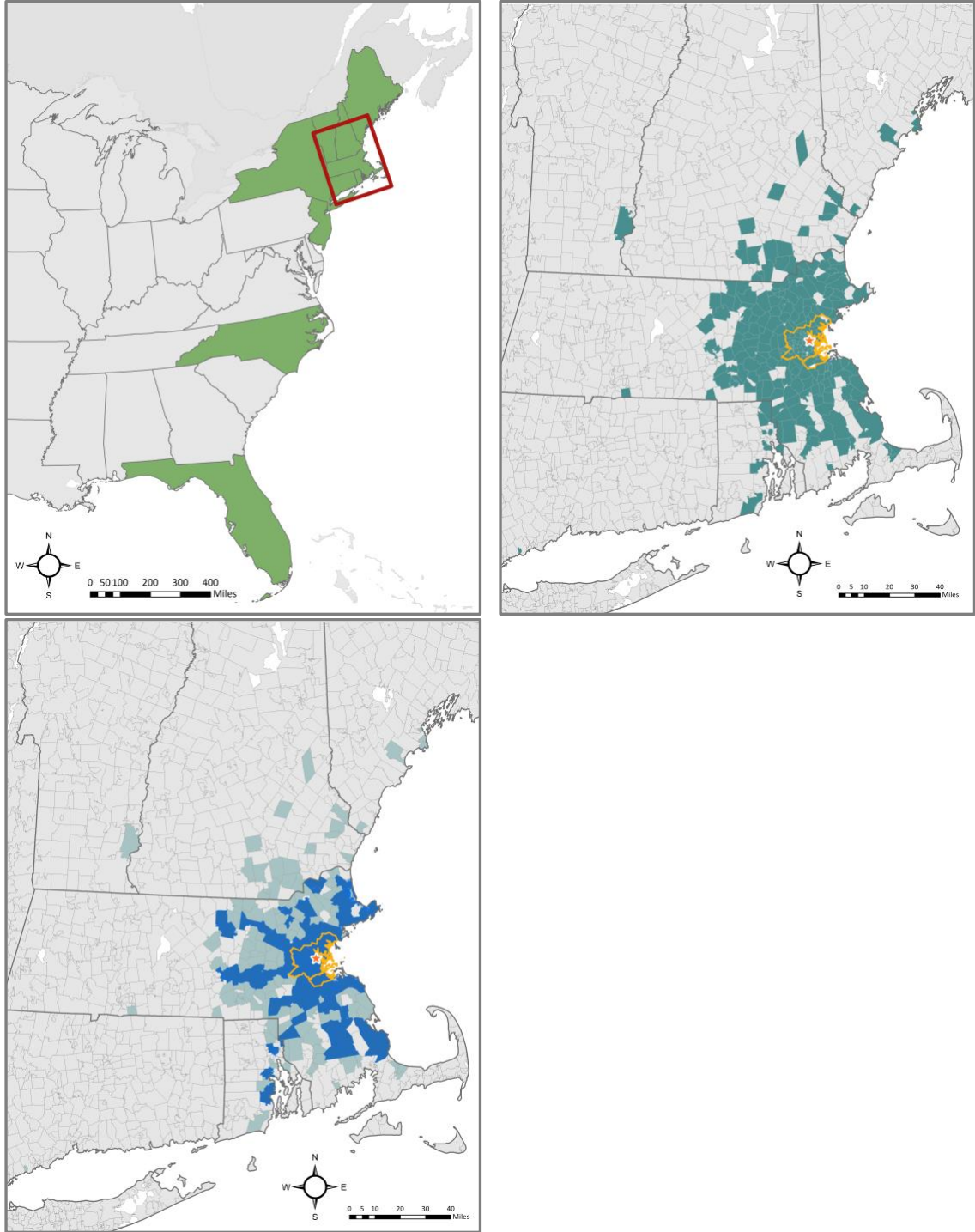


Figure 9. Map showing the distribution of survey participants' origin locations.

In the latter two figures, the yellow border represents the “Inner Core” communities as defined by MAPC (“21 cities and towns within the metropolitan Boston area”). The study area is symbolized by an orange star. **Figure 9a** (top left). The 10 states from which survey respondents reported beginning their commutes. The red box illustrates the extent of Figures 9b and 9c. **Figure 9b** (top right). New England zip codes from which employees begin their commutes (teal). **Figure 9c** (lower left). New England zip codes that are at least partially accessible to transit walksheds (blue). The background teal zip codes reflect the origin zip codes of survey participants.

Table 5. Public transit use based on transit accessibility.

In general, public transit use among employees beginning their commutes from zip codes that are accessible to transit increases as land area accessible to transit increases.

| Land area accessible to transit | Zip codes (total 169) | Participants within valid zip codes | Proportion of total participants (2,353) | Public Transit Use Among Employees | | |
|---------------------------------|-----------------------|-------------------------------------|--|------------------------------------|-------------|-------------|
| | | | | 3+ times/wk | 4+ times/wk | 5+ times/wk |
| N/A | 270 | 2,341 | 99.5% | 48.5% | 41.8% | 31.8% |
| > 0% | 169 | 2,168 | 92.1% | 49.0% | 44.6% | 36.5% |
| > 25% | 75 | 1,538 | 65.4% | 48.4% | 45.1% | 38.8% |
| > 50% | 65 | 1,398 | 59.4% | 48.0% | 44.4% | 38.5% |
| > 75% | 49 | 1,265 | 53.8% | 54.6% | 50.0% | 43.6% |

Figure 10 illustrates the existing public transit infrastructure in the study area. The modes included in this analysis include the commuter rail stations, the T stops, and the bus stops within the Inner Core Communities, as defined by the MAPC. Transit accessibility is displayed in Figure 11 and calculated through the generation of walksheds surrounding the three forms of public transit, listed above.

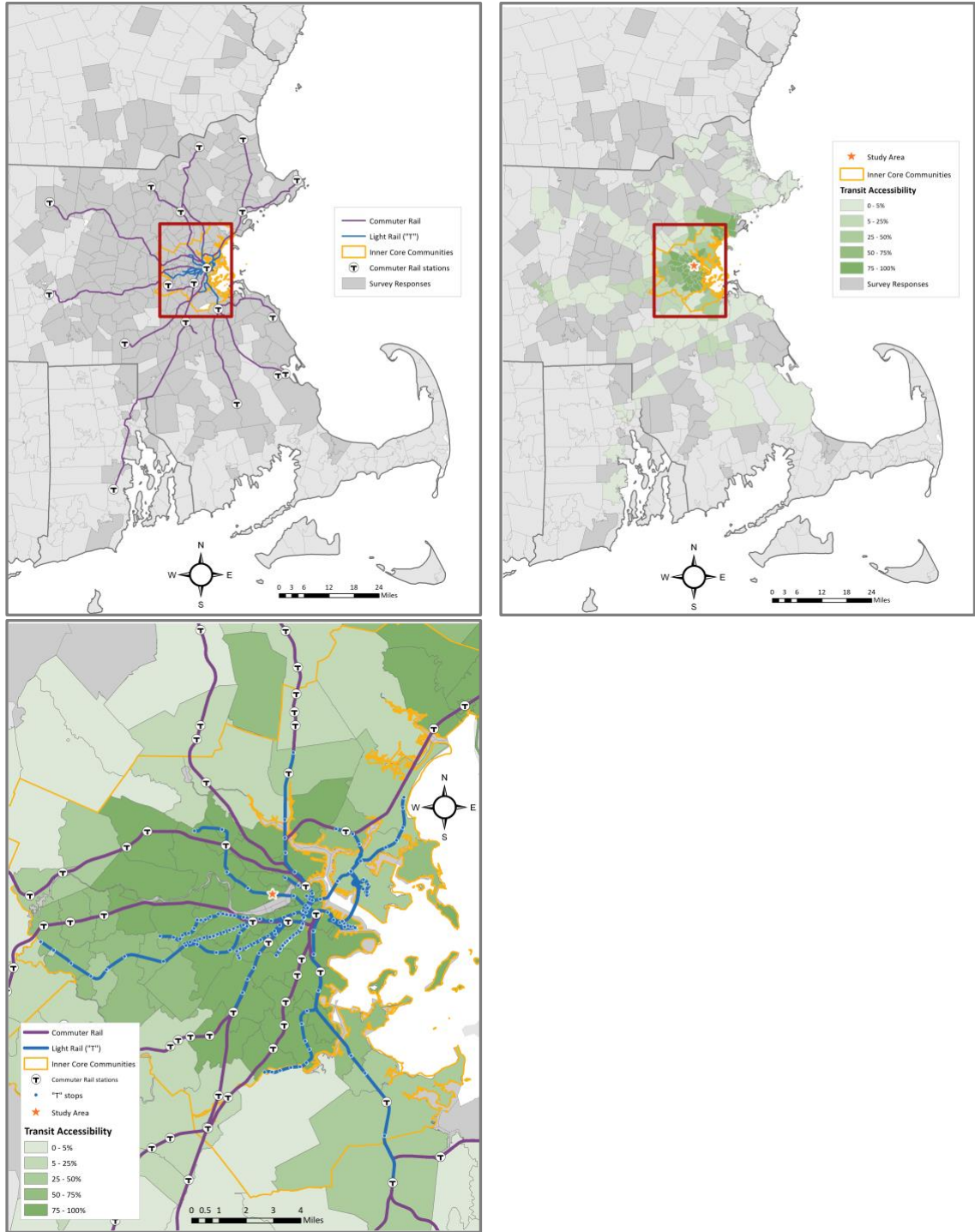


Figure 10. Public transit accessibility.

The red boxes illustrate the extent of Figure 10c. **Figure 10a** (top left). Existing public transit infrastructure. The terminal and common commuter rail stations are shown by the MBTA symbol. The darker gray zip codes reflect the origin zip codes of survey participants. **Figure 10b** (top right). Public transit accessibility within the zip codes that intersect with a public transit walkshed. The darker gray zip codes reflect the origin zip codes of survey participants. **Figure 10c** (lower left). Public transit infrastructure and accessibility within the Inner Core Communities. Commuter rail (purple), the T (blue), and their corresponding stations are shown. Bus stops are not shown in this figure because of their high density, visualized in Figure 11c.

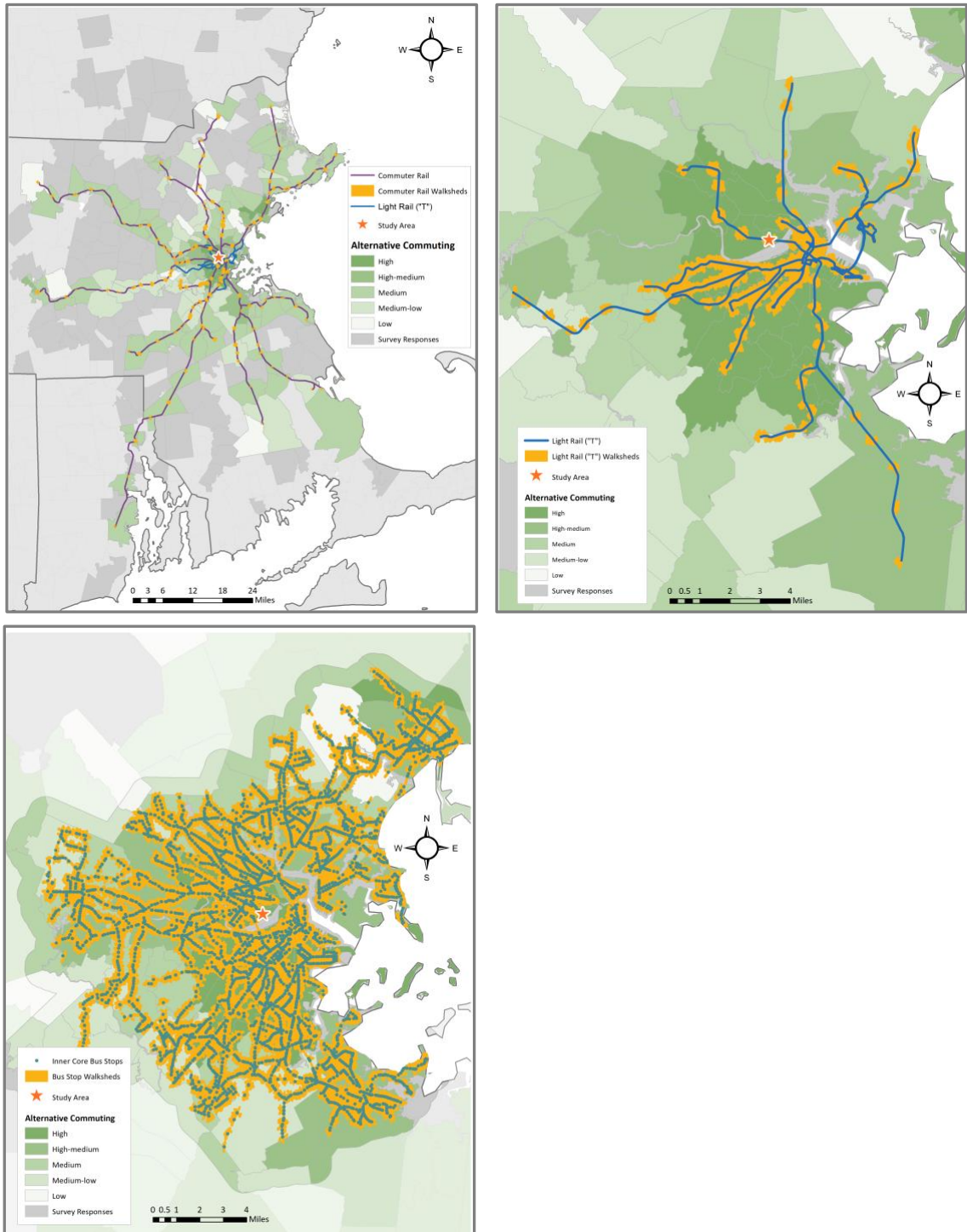


Figure 11. Public transit walksheds.

The rate of alternative commuting is shown as a gradient in the zip codes that are at least partially accessible to public transit. **Figure 11a** (top left). Transit walksheds surrounding commuter rail stations (1/2-mile). **Figure 11b** (top right). Transit walksheds surrounding light rail ("T") stations (1/4-mile). **Figure 11c** (lower left). Transit walksheds surrounding bus stops (1/4-mile) within MAPC's Inner Core Communities.

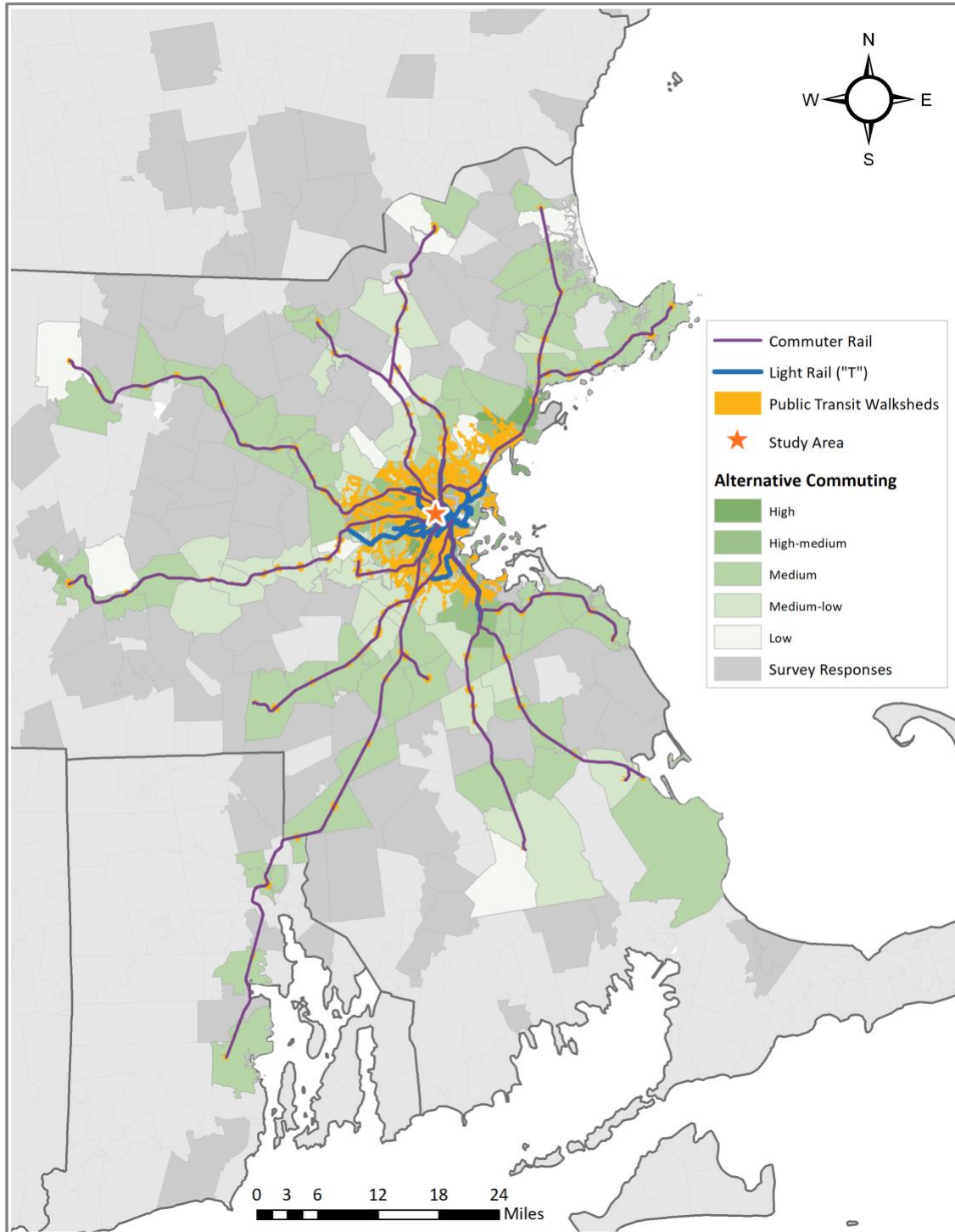


Figure 11d. Combined public transit walksheds represent transit-accessible areas.

Based on the watershed analysis, there are 75 zip codes whose land area is at least 25% or more accessible to transit, as shown in Figure 12a. While 75 represents only 26.7% of the total number of zip codes (281), the number of respondents originating in these zip codes (1,582) represent 67.2% of the total number of employees who provided a valid zip code. Based on a more focused analysis of the zip codes that have 25% or more land area accessible to transit and are within the upper (population) quartile, transit is well-utilized. Although 25% transit accessibility was the lower bound for this more focused analysis (Figure 12a), because of the additional population criterion (Figure 12b), the selected zip codes range from 31.8% to 100% accessible. This subset of 34 zip codes represents 55.8% (1,313) of the survey respondents who provided zip codes (Figure 12c).

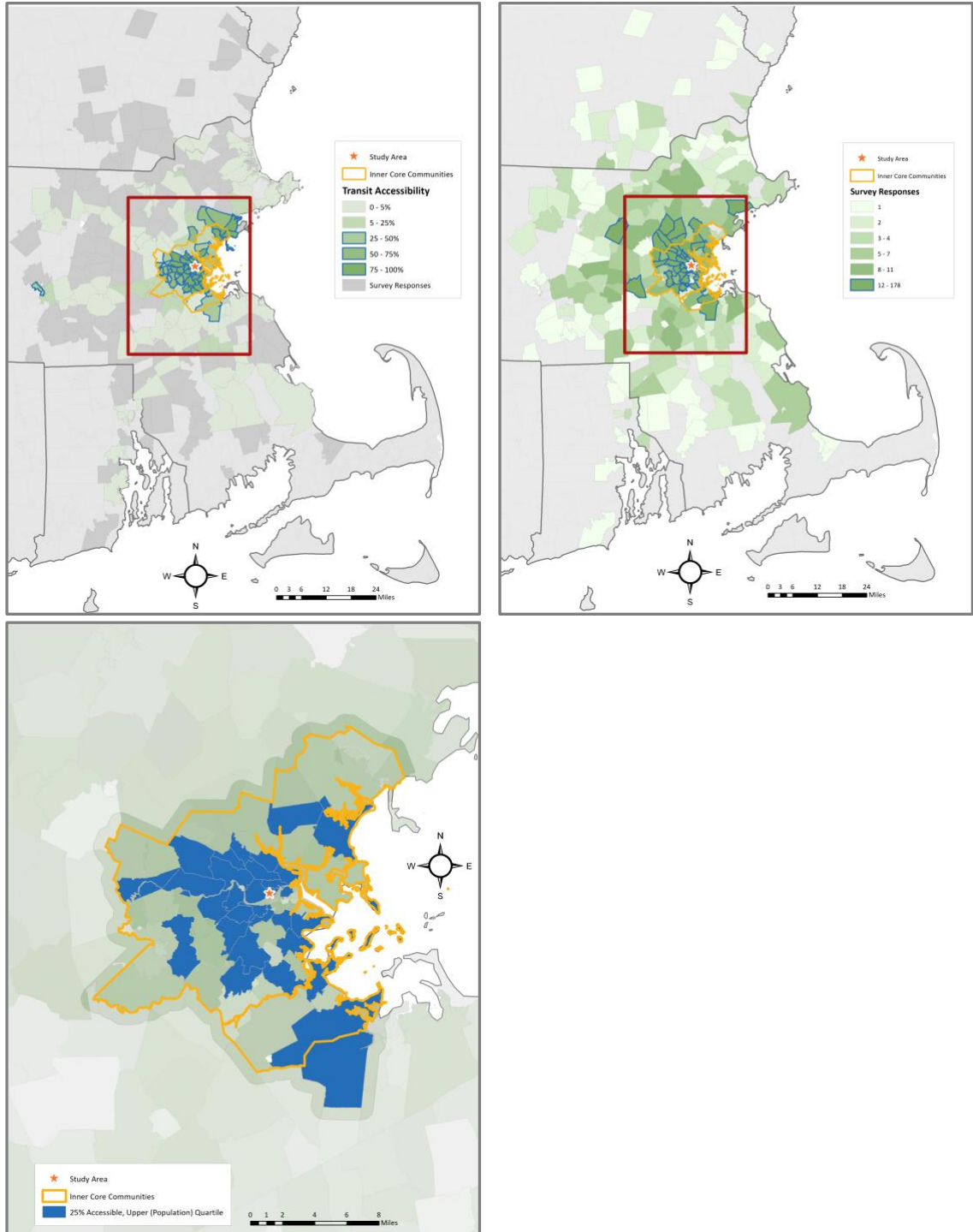


Figure 12. A subset of zip codes displayed against transit accessibility and population criteria.

The red boxes illustrate the extent of Figure 12c. **Figure 12a** (top left). The 75 zip codes that are at least 25% accessible are outlined in blue. The rate of transit accessibility is shown as a gradient in the zip codes that are at least partially accessible to public transit. **Figure 12b** (top right). The 46 zip codes with the upper (population) quartile are outlined in blue. The frequency of survey response origin locations is shown as a gradient. **Figure 12c** (lower left). The 34 zip codes that are at least 25% accessible to transit and contain the upper (population) quartile.

This analysis compares the average rates of alternative transportation commuting modes (4 or 5 times a week) within each zip code to the proportion of the zip code land area that falls within a transit walkshed in order to approximate the connection between transit accessibility and the realistic utilization of existing infrastructure. Because transit accessibility rates of alternative commuting modes would be expected to be positively correlated, transit overutilization and underutilization for a zip code that is 50% accessible to transit should theoretically have alternative commuting rates of greater than 50% or less than 50%, respectively.

The majority of these 34 zip codes have a high rate of alternative commuting (Figure 13a) with only one of the zip codes being underutilized (Figure 13b). The rate of alternative commuting is highest for participants beginning their commutes in zip codes that are accessible to the T's Blue Line, followed by the Red Line and the commuter rail (Figure 14). Although the Blue Line may have a higher rate of alternative commuting, the numbers of zip codes and participants that correspond to this transit route are much lower than the other routes.

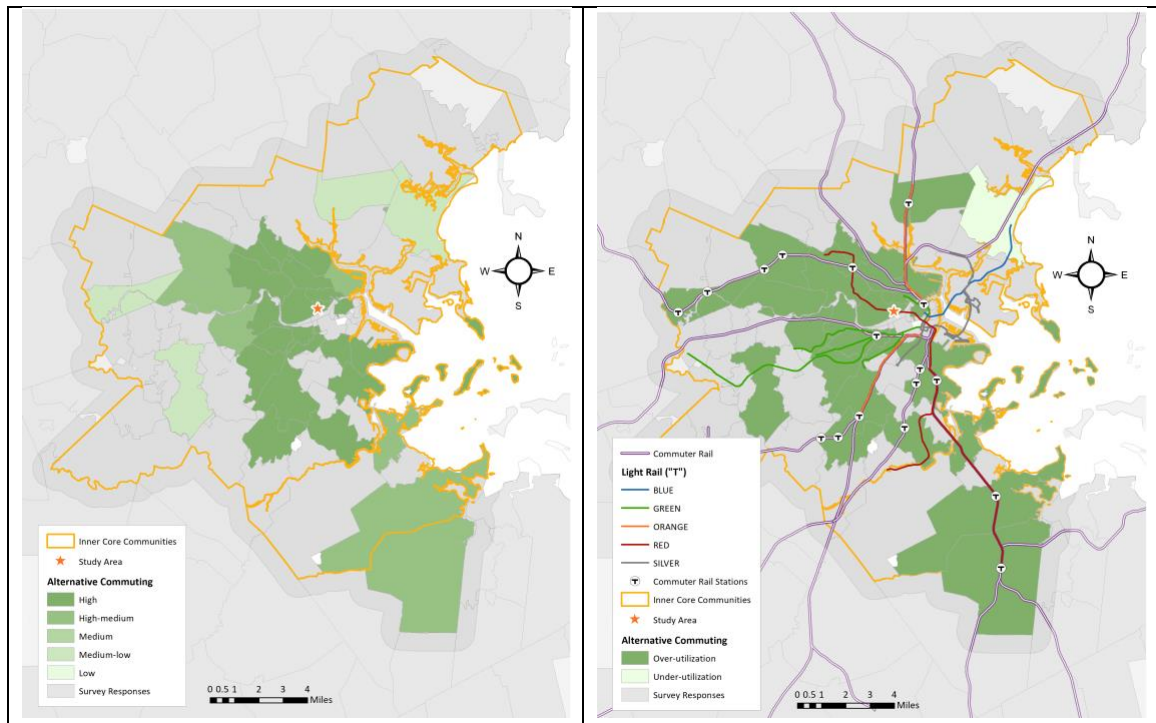


Figure 13. The 34 zip codes of focus based on transit accessibility and population criteria.

These zip codes are at least 25% accessible to public transit, based on walkshed and land area, and contain the upper (population) quartile. **Figure 13a** (left). The rate of alternative commuting is shown as a gradient. Alternative commuting ranges from (-1.0) to 1.0, with smaller (negative) values representing low alternative commuting use and larger (positive) values representing high levels of alternative commuting use: Low [(-1.0)-(-0.6)], Low-medium [(-0.6)-(-0.2)], Medium [(-0.2)-0.2], Medium-high (0.2-0.6), High (0.6-1.0).

Figure 13b (right). Over- and under-utilized transit services in relation to the proportion of the zip code land area that is transit accessible. Over-utilized is considered positive values (>0), and under-utilized is categorized as negative values (<0).

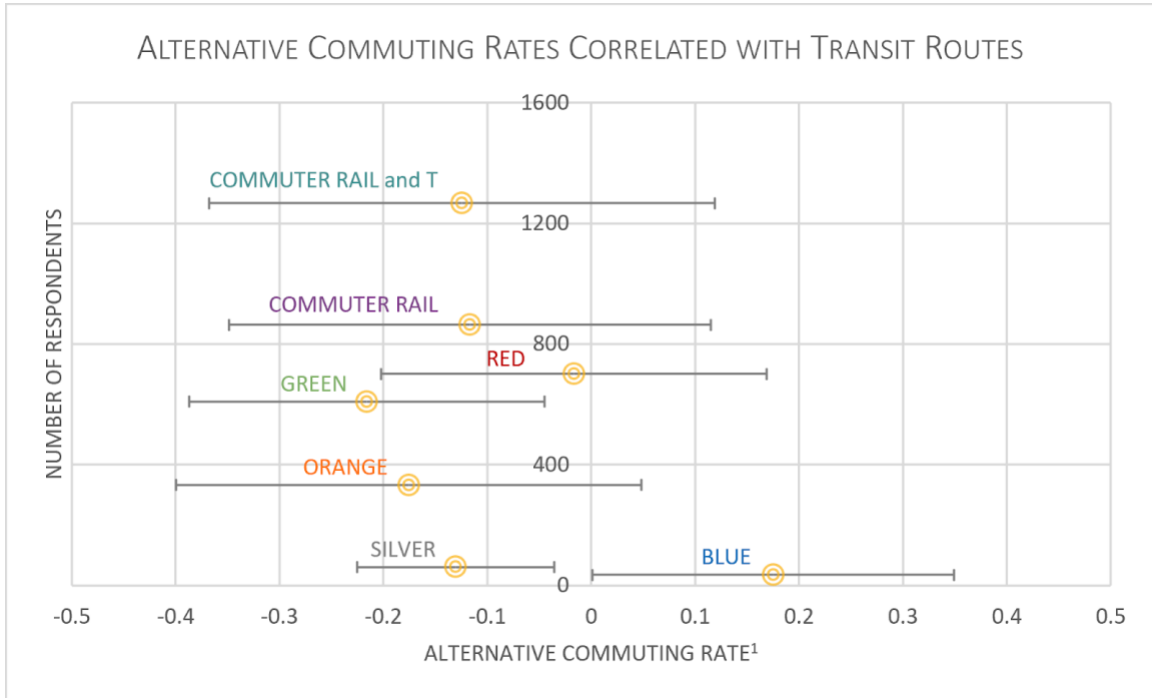


Figure 14. Rates of alternative commuting use correlated to the different transit routes.

The colors correspond to the MBTA subway lines. This chart does not include bus utilization.

¹ The alternative commuting rate was calculated by subtracting the percent of transit-accessible land within each zip code from the percent of zip code respondents that report using active or public transit 4 or 5 times within the survey week. This value ranges between -1 (no alternative commuting in a zip code that is fully accessible to public transit) and 1 (all participants report alternative commuting from a zip code that is not accessible to public transit). The larger the value, the more alternative commuting used among survey participants in the zip codes correlated to the specific transit routes.

5.2.3 Distance

Homogeneity of variance among employee alternative commuting rates for those reporting different commuting distance ranges (0-10mi, 11-20mi, 21-40mi, 41-60mi, and 60+ mi) is violated, *Levene's test* $F(4, 2348)=26.37, p<0.001$; thus requiring the application of Welch's test. Distance significantly impacts the rate of alternative commuting (active and public transportation) among employees, *Welch's* $F(4, 129.94)=51.37, p<0.001$. A Games-Howell post-hoc test reveals that the significant differences in alternative commuting rates occur between specific distance ranges. Employees reporting a 0-10 mile commute report significantly higher rates of alternative travel when compared to

those commuting 11-20 miles ($p < 0.001$), 21-40 miles ($p < 0.001$), and 41-60 miles ($p < 0.05$). The eta squared ($\eta^2 = 0.09$) suggests that approximately 9% of the total variation in alternative commuting rates can be attributed to differences in origin distance, a relationship that falls within the medium-large benchmark ranges, as defined by Cohen (1988).

Similarly, because the homogeneity of variance for employee telecommuting rates is violated among distance groups, *Levene's test* $F(4, 2348) = 94.10$, $p < 0.001$; this analysis requires the use of Welch's test. Distance significantly impacts the rate of telecommuting among employees, *Welch's F* ($F(4, 127.019) = 22.29$, $p < 0.001$). A Games-Howell post-hoc test reveals that employees reporting a 0-10 mile commute report significantly lower rates of telecommuting when compared to those commuting 11-20 miles ($p < 0.001$), 21-40 miles ($p < 0.001$), and 41-60 miles ($p < 0.001$). The eta squared ($\eta^2 = 0.06$), indicates that approximately 6% of the total variation in telecommuting rates can be attributed to differences in origin distance, a medium benchmark range, as defined by Cohen (1988).

5.2.4 Promoting Alternative Modes of Transportation

Out of the 2,364 survey responses, 42% (993) of respondents chose at least one of the pre-selected options (mean = 4.2, median = 4) and less than 2% (41) respondents provided additional open ended responses.

For the employees who chose to select from the survey-provided options, 33.2% of all respondents (785) indicated that convenience contributed to their choice to take alternative commuting modes. As seen in Figure 15, cost, time efficiency, and environmental concerns are the second (25.8%, 611), third (21.2%, 501), and fourth (17.6%, 417) most frequently indicated reasons for choosing to use alternative forms of transportation, respectively. A full list of the ranked choices is available in Appendix D.

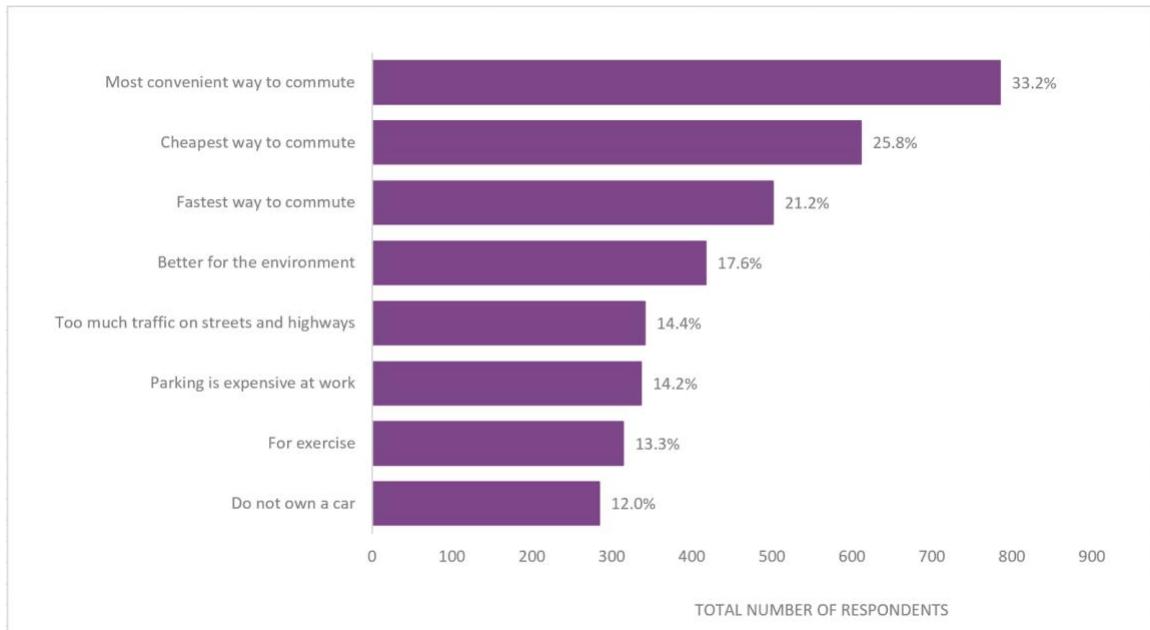


Figure 15. The most frequently chosen reasons for commuting by alternative modes of transportation. The options shown above represent a subset of the total 14 choices provided within the survey (Appendix B). The percentage values reflect the proportion of the total number of survey respondents (2,364) who chose each reason.

When providing open responses, one of the most frequently mentioned reasons for choosing to take alternative modes is the ability to use the time spent commuting for other activities or work. Out of the 41 responses, 19.5% (8) participants provided responses that fell into this category. The second and third most frequently mentioned responses are the ability to coordinate carpooling with family or friends (14.6%, 6) and stressful or difficult driving conditions (7.3%, 3), respectively. More detail about the categorization process is in Appendix D.

Synthesizing the more specific response categories into broader categories provides a way to observe whether the open response reasons are within the personal control of individual employees or influenced by external factors. While the majority of the responses fall within the realm of personal responsibility, examples of external factors that were mentioned more than once include unavailable parking and vehicle unavailability.

5.3 Theme 3: Awareness of Existing Services and Incentives

While awareness of incentives is dependent on the company and specific incentives, survey results indicate that many employees are unaware or unsure about employer-provided incentives and benefits.

When employees were asked to indicate whether their company provided any of the 10 pre-selected incentives, there was an average 49.9% response rate. Out of these respondents, an average of 44.0% indicated that they were “not sure,” a higher value than the 39.7% and 16.4% who indicated that their companies did or did not provide the incentives, respectively. Because each company provides a unique combination of incentives, the interesting value is that almost half of the participants are unaware if these specific services are available to them. These trends are similar for the two incentives which correspond between the employee and employer survey - transit subsidies and on-site information.

Twelve of the 17 companies indicated that they do provide subsidized MBTA Transit Passes, affecting 69.4% (1,627) of survey respondents, as shown in Table 6. For those employees working at companies that do provide transit subsidies, over half of the responses (56.7%, 471) indicated an awareness of transit subsidies, while 34.5% (287) indicated that they were not sure.

Close to half of the employees working for companies that do not provide transit subsidies and that responded to this question (45.9%, 168) indicated that they were aware of a subsidy for transit, and 40.4% (148) indicated that they were not sure. These results indicate both a misconception and a lack of awareness regarding company commuting-related subsidies. Only 13.7% (50) of employees providing survey responses were correct in responding that their companies do not provide subsidies for transit.

Table 6. Employee awareness of employer-provided transit benefits.

Employee-awareness of transit and vanpool subsidies is compared against the actual employer-provision of this specific type of commuting benefit. The percentage values reflect the proportion of employees who responded to this specific prompt by indicating one of the three provided choices (“No”, “Yes”, and “Not Sure”). The columns to the right show the difference between the employees responding to this prompt and the total number of employees working at companies that do or do not provide this benefit. Overall the response rate across companies that do and do not provide transit subsidies is approximately 50%.

| | | Awareness of subsidy for ”transit/vanpool fares” (employee survey) | | | Total number of employees who... | |
|--|----------|--|-------------|-------|----------------------------------|----------------------------|
| | | No | Not Sure | Yes | Indicated an awareness | Provided their employer |
| Employer- provided subsidized transit (employer survey) | No | 13.7% | 40.4% | 45.9% | 366 | 700 |
| | Yes | 8.8% | 34.5% | 56.7% | 831 | 1,627 |
| | unknown* | 22.2% | 22.2% | 55.6% | 9 | 18 |

*unknown refers to the employees working at companies that did not provide complete information about their benefits packages in the employer survey

Out of the 17 companies included in this research, four responded that they do post MBTA and/or EZRide schedules in central locations, affecting 42.8% (1,003) of survey participants (Table 7). The availability of information is a more inconsistent service provided by the employer because of the variety of ways that this information can be presented and shared with employees. Despite this ambiguity, the general awareness trend remains the same, with the majority of participants indicating that they are not sure. For employees at companies that do not post schedules in central locations, over half (54.1%, 326) are not sure of available information, with the remaining respondents split between believing there is and is not information available. For employees at companies that do post schedules in central locations, almost half (48%, 277) indicated that they were aware of on-site information, while 39.3% (227) and 12.7% (73) indicated that they were unsure and were not aware, respectively.

Table 7. Employee awareness of employer-provided on-site information.

Employee-awareness of on-site information is compared against the actual employer-provision of this specific type of commuting service. The percentage values reflect the proportion of employees who responded to this specific prompt by indicating one of the three provided choices (“No”, “Yes”, and “Not Sure”). The columns to the right show the difference between the employees responding to this prompt and the total number of employees working at companies that do or do not post information in central locations. Overall the response rate across companies that do and do not provide transit information is approximately 50%.

| | | Awareness of “on-site information on transit routes and schedules” (employee survey) | | | Total number of employees who... | |
|--|----------|--|----------|-------|----------------------------------|-------------------------|
| | | No | Not Sure | Yes | Indicated an awareness | Provided their employer |
| Information posted in central locations (employer survey) | No | 23.3% | 54.1% | 22.7% | 603 | 1,324 |
| | Yes | 12.7% | 39.3% | 48.0% | 577 | 1,003 |
| | unknown* | 33.3% | 33.3% | 33.3% | 9 | 18 |

*unknown refers to the employees working at companies that did not provide complete information about their benefits packages in the employer survey

When indirectly prompted, three companies representing 500 employees indicated that they do provide biking and walking incentives. Similar to the previous results, almost half of the employees (48.8%, 157) provided with these incentives and who responded to the question indicated that they were not sure about “financial incentives for biking and walking,” with 32.3% (104) and 18.9% (61) indicating that they were and were not aware of these incentives, respectively. This is more difficult to quantify based on survey design - not all companies provided a response to this open-ended question at the end of the

employer survey and the three that did mention biking and walking-related benefits did not provide more specific details regarding the type of incentive offered. Because of the limitations of these data, the results may not be fully representative of employee awareness in relation to this subset of incentives.

5.4 Theme 4: Potential to Incentivize a Mode Switch

Out of the 2,364 survey responses, 48.2% (1,140) of respondents chose at least one of the 15 pre-selected options (mean = 14.6, median = 15) when answering the question: “What would cause you to switch from driving alone to another mode of transportation?” In addition, 20% (473) of respondents chose to provide an open-ended response.

Across the 15 pre-selected potential incentives, there is an average of 1,070 employees who chose to respond to at least one of the potential incentives. The average percentage of respondents indicating that they would be “not likely” to switch commuting modes if provided with the pre-selected incentives is over 3.5 times the average number of respondents who indicated they would be “somewhat likely” or “very likely” to shift commuting behavior, indicating that even with the provision of incentives, the majority of respondents are unlikely or hesitant to switch.

Subsidies for transit fares and financial incentives were selected as the incentives that would “very likely” encourage employees to switch from driving alone to using alternative modes, according to 31% (337) and 29% (313) of participants who responded to these questions, respectively. Despite this, 51% (552) and 57% (611) of participants who responded to these questions indicate that these incentives would “not likely” encourage a switch, respectively.

When asked about switching to alternative commuting modes if provided with a subsidy for transit fares, 1,082 employees selected one of the three provided responses. Overall, those who indicated that they would be “very likely” to switch already use public transit at higher rates, followed by the employees who indicated that they would “somewhat likely” and “not likely” switch (Figure 16). The higher rates of commuting by public transit for employees that work at companies that already provide transit subsidies further supports the finding that transit subsidies increase the use of more sustainable commuting modes.

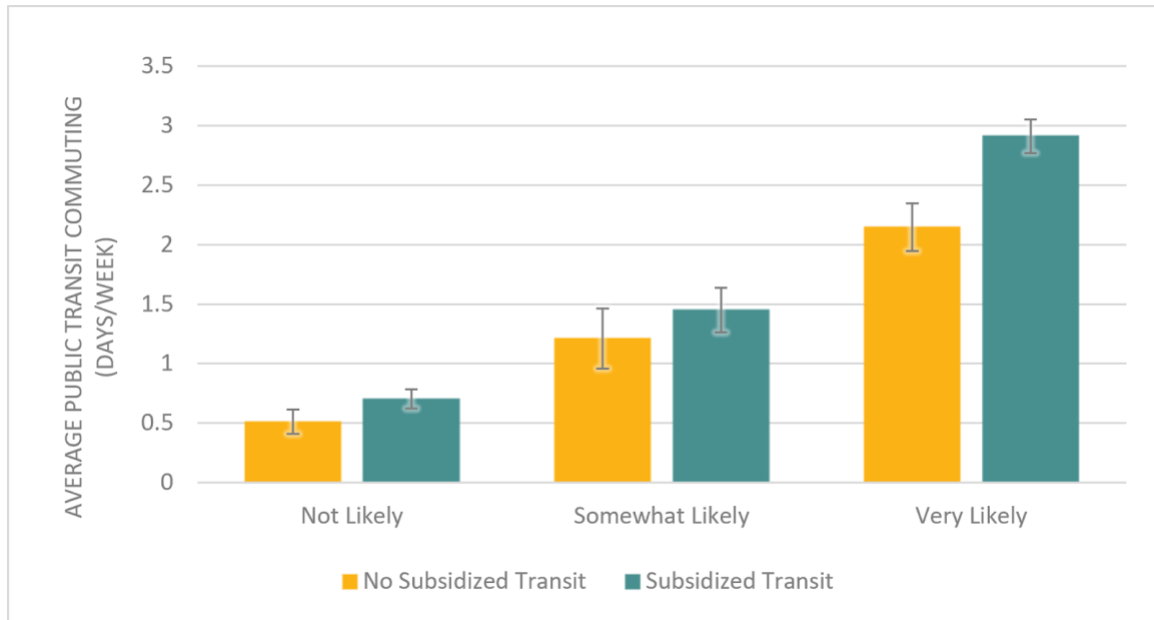


Figure 16. Employees’ willingness to switch commuting modes if provided with transit subsidies.

Employee responses (x-axis: “not likely”, “somewhat likely”, and “very likely”) are compared to their reported public transit rates (y-axis: average number of days/week participants use public transit). The teal represents employees at companies that already report providing public transit subsidies, while the employees at companies that do not provide subsidies are represented by yellow.

Increases in on-site parking fees by 10% or more is the TDM strategy that employees identified as the least likely to encourage a switch, according to over 76% (801) of participants who responded to this question. This result relates to the finding that the availability and provision of parking is one of the most significant indicators of whether an employee will choose to commute by SOV.

When asked “What would cause you to switch from driving alone to another mode of transportation?” 473 participants provided open responses. Some respondents provided more than one reason, resulting in 520 distinct suggestions. Synthesizing these responses into 41 specific categories and 9 broader categories helped to establish the common and most important factors influencing employees (Figure 17). Over one-third (33.8%, 160) of the responses included language indicating that an improved public transportation system may encourage a mode shift, making it the most frequently mentioned response. Within this broader category, respondents indicated that reliability, frequency, and accessibility are the highest priorities. The second most frequently mentioned response was that nothing would influence a shift (16.1%, 76). While many of the respondents who wrote that they would not be convinced to shift modes mentioned family commitments, the second-largest subset did not provide any additional explanation. The third most frequently mentioned reason for potentially changing commuting modes

classifies as personal (14.6%, 70) with equal numbers of respondents attributing their current commuting choices as being influenced by personal commitments and their housing locations.

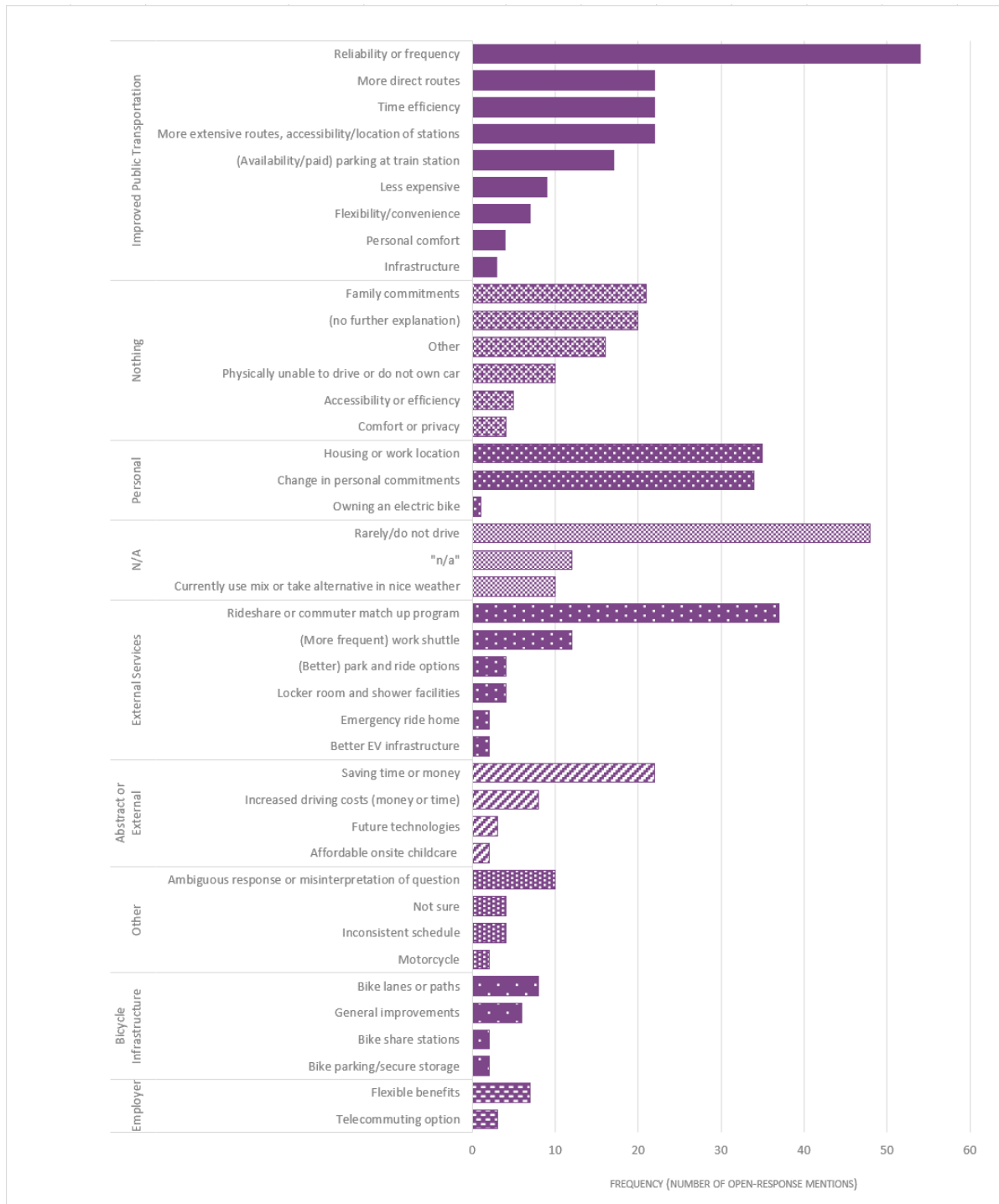


Figure 17. Open-ended responses for reasons that would prompt a commuting shift.

When prompted with the question, “What would cause you to switch from driving alone to another mode of transportation?” 473 participants provided 520 reasons. The more specific responses (right) are organized into broader themes (left), organized from most frequently mentioned to least frequently mentioned, within each theme.

To begin initiating a shift away from commuting by SOV, it is important to identify the parties that are responsible for initiating and supporting the necessary systemic changes. Based on the open-response suggestions provided by survey participants, there are five main stakeholders or responsible parties (government, personal, partnership, external/abstract, and company/developer), along with ‘other’ and ‘not applicable’ categories (Figure 18; more detail about the categorization process is in Appendix D). Over one-third of the changes that participants mentioned when responding to this open-ended question fall within the jurisdiction of the government (34.2%). The potential changes or reasons classified as personal, such as family commitments, housing/work locations, and physical limitations, account for 21.2% of participant suggestions. The changes that could be implemented by the employers account for a smaller portion (5.8%) of the suggestions.

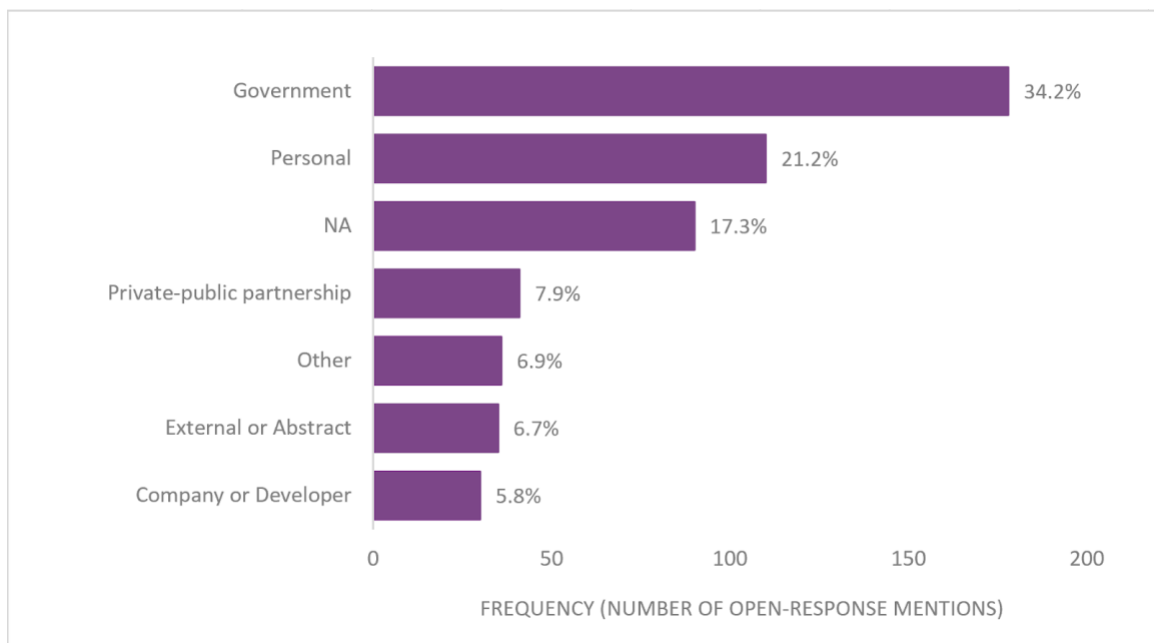


Figure 18. The stakeholders responsible for implementing participants’ open-ended suggestions. The percentage value reflects the frequency of suggestions (total 520) falling within the jurisdiction of each stakeholder.

CHAPTER 6 DISCUSSION

This thesis highlights the important measures that employers can take to reduce employee SOV commuting rates. To encourage and support a shift toward more sustainable commuting modes, alternatives to SOVs must become viable options. Instead of addressing this challenge by enacting isolated, superficial measures, improving transportation should be regarded as a multi-faceted issue that requires innovation, collaboration, and flexibility. As opposed to condemning the use of automobiles and solely promoting the use of public or active transportation modes, programs, and benefits packages should account for the nuanced needs of employees. By aligning convenience, cost, well-being, and sustainability goals, employers can help to make the right choice the easier choice. This more comprehensive approach to employer-led initiatives can empower employees to make the optimal choice that accommodates their responsibilities while also helping to reduce environmental impact.

Because initiating employee commuting shifts will require changes at a variety of dimensions, this discussion also introduces larger-scale considerations that require cross-sector collaboration. There are numerous stakeholders, partnerships, and existing systems in place that strongly influence the environment in which the transportation system functions. Although improvements to public transit and policy reform are not within the direct responsibility of individual companies, regional transportation infrastructure and policy directly impact employees and the ways they choose to access their jobs. Employers thus have an important role in advocating for their employees by becoming actively involved in the conversations regarding these external influences. Encouraging a widespread shift toward more sustainable transportation behavior will require a comprehensive understanding of the ways these factors interact with and rely upon one another.

6.1 Employer Efforts: Incentives and Benefits Programs

6.1.1 Company Engagement

Improving employer-provided incentives and benefits programs have the potential to inspire personal changes in commuting behavior, resulting in larger, more widespread shifts. One of the first steps

to shifting commuting behavior at a company-wide level is an engaged employer who is invested in creating a supportive environment for alternative commuting modes (Gutman 2017; Su and Zhou 2012). According to Michele Brooks, the Vice President of TransAction, encouraging thoughtful commuting options represents just one of a company's many competing priorities. In addition, the benefits of implementing these programs are often difficult to measure and quantify (Brooks 2020). Despite these challenges, there are numerous reasons that employers may strive for reductions in employee SOV rates. These goals may be based on considerations such as the high cost of providing parking, the benefits of encouraging a healthier workforce and improving productivity, and the desire to promote sustainable behavior. In addition to these economic and environmental considerations, many of the employers made the decision to locate in Cambridge's Kendall Square neighborhood because of the cultural amenities and city services that are attractive to potential employees. Based on this choice, many companies are interested in supporting and advocating for measures that perpetuate this type of vibrant, pedestrian-friendly environment and culture.

6.1.2 Understanding that Employees Have Unique Needs

Benefits programs and commuting incentives provided to employees have the potential to encourage the use of certain modes of transportation over others, but they must be provided in a way that supports the needs of employees. When the TransAction survey asked respondents for their reasons for choosing to commute by SOV, personal commitments and family responsibilities were both the most frequently chosen pre-selected options and the most frequently cited open-ended responses. In contrast, when the TransAction survey asked respondents to provide reasons for choosing alternative modes, many mentioned using their commuting time for other activities. Despite these differences, convenience and time were within the top 3 reasons for both forms of commuting. These results highlight the range of complex factors that influence commute decision-making. While some employees may find commuting by public or alternative modes more convenient because of their personal schedules or housing locations, convenience for others can translate to driving.

This variation between employees extends beyond family responsibilities and spatial distribution, to also include personal background and experience. Educational attainment, gender, age, and income are

additional characteristics that influence an individual's preference for certain commuting modes (Habibian and Kermanshah 2013; Ding et al. 2017; Lind et al. 2015; Panter et al. 2013; Tajalli and Hajbabaie 2017; Ye and Titheridge 2017). Therefore, employers must think about creating and providing benefits programs that address and accommodate the unique and complex needs of their employees.

Although commuting choice is heavily dependent on personal factors over which employers may have little or no control over, employers can still play a role in making alternative commuting modes more convenient. They can accomplish this by helping to make alternatives, including public transit, biking, walking, and carpooling, more time- and cost-effective. By rethinking the ways incentive and benefits programs are administered and structured, employers can have a strong influence in making the choice to take alternative transportation a more attractive option.

6.1.3 Incorporating More Flexibility

The provision of benefits influences commuting behavior, with subsidized transit associated with increased public transit use (Herzog et al. 2006; Bueno et al. 2017) and free parking associated with increased SOV commuting (Willson and Shoup 1990; Hess 2001). While the majority of employer commuting programs provide their employees with a choice between subsidized transit or free parking, often provided on a monthly basis, this traditional binary benefit structure is limiting. Instead of accommodating the needs of individuals, having to choose between benefits assumes that personal responsibilities and commitments remain consistent throughout the month. Survey respondents frequently mentioned this limitation when providing open-ended responses to explain their reasons for driving alone.

Based on this research, inadequate public transportation infrastructure represents one major consideration impacting employee commuting behavior. Many identify the difficulty of relying on public transit when it requires driving to public transit stations that may or may not have enough parking, a challenge also addressed in *The Boston Globe* article "One big barrier to MBTA ridership? Not enough space for cars" (Vaccaro 2019). In addition to insufficient parking, many garages and lots at the commuter rail or terminal T stations charge for parking. This added fee, in addition to the cost of the transit fees can make it more expensive to take public transportation from the suburbs surrounding the City. In addition to the uncertainty of being able to park and the financial costs of using multiple modes of transportation,

survey participants also mentioned the added time of transferring between modes as a consideration when choosing to drive alone.

Another consideration that could potentially impact employee choice is the tendency for monthly parking subsidies to be worth a higher monetary value when compared to the cost of a monthly transit pass. This is the case for many of the companies studied in this research. If employees anticipate requiring their cars a few times a month, it is often more economical for them to choose the subsidy for parking and supplement the ad hoc transit costs (about \$13 for an unlimited bus and T 1-day pass). In comparison to the amount for a daily transit pass, average daily parking rates are much higher (ranging from \$25 to \$45 per day at nearby garages, depending on the amount of time parked). Therefore, if employees are choosing the commuting benefit that provides the best option in terms of time and money, many see free parking as the more attractive option.

Because the traditional, either-or benefit structure does not take into account the needs of employees, flexible policies are more effective when trying to shift commuters away from SOV use (Gutman 2017; Lutenecker 2017). In Seattle, when daily fees replaced monthly parking fees at The Gates Foundation and Delta Dental, both companies observed noticeable reductions in solo commuting rates (Gutman 2017). Similarly, in a study at UC Berkeley, parkers cited a desire for parking permits in smaller time increments (Riggs and Kuo 2015). Researchers found that it may be difficult for many drivers to make long-term and full-time commitments to not driving. Adjusted parking fees provide an alternative that would allow employees to drive less frequently. As Jonathan Hopkins, director of Commute Seattle, explained in *The Seattle Times*, monthly parking fees represent an “incentive to continue parking” (Gutman 2017). Because the monthly fee represents one large, upfront payment, individuals continue to drive and park because they recognize that choosing to use another mode would cost them additional money. Therefore, taking advantage of the benefit for which they have already paid is less expensive and requires less personal effort. This reasoning is closely related to the behavioral economic concepts of loss aversion and pain of paying, both of which explain human tendency to avoid situations in which losing money is a possibility (Ott 2018). When the transportation benefit is binary, once the user pays the fee, it is “free” for the rest of the month.

Daily parking fees provide an alternative payment structure by increasing the perceived money spent. Instead of feeling the need to get the most value out of their monthly parking payment, a sunk cost, individuals are forced to consider the cost of parking each time they want to drive. A pilot program led by MIT in Cambridge, MA called Access MIT, further supports these findings. Ms. Westwater, the Vice President of Strategy and Operations of the Kendall Square Association, emphasized the importance of acknowledging that commutes are complicated (Westwater 2020).

The traditional transportation benefit model does not meet employees' unique needs. Given this understanding and recent research, Ms. Westwater advocates for transportation benefits that allow for increased flexibility, empowering employees to make the best decision based on the day (Westwater 2020). Implementing a model that incorporates more flexibility in transportation benefit uses has the potential to initiate a more sustainable mode split as employers grant employees more options to accommodate their personal needs and circumstances. As Hayden, Tight, and Burrow (2017) recommend, transportation policy makers and planners should actively engage with stakeholders to understand the target populations they are attempting to serve. Through increased participation and representation, employees can advocate for strategies and programs that are most appropriate for their schedules and needs (Hayden, Tight, and Burrow 2017). And while shifting from the broad "one size fits all approach" to a new, more nuanced system may require additional effort from employers and transit providers, this shift in thinking will be beneficial in the long-run by advancing the larger goals of the community.

6.1.4 Comprehensive Benefits Packages

One of the main goals of PTDM strategies is to optimize the use of all available transportation options by encouraging the use of alternative modes of transportation, while simultaneously reducing the number of SOVs. This thesis research focuses on the role of subsidies and incentives to inspire mode shifts; however, disincentives can act as additional complementary measures when part of a comprehensive program.

6.1.4.1 Incentives

Incentives motivate individuals to behave in certain ways or make choices that will result in a reward or beneficial outcome, while subsidies encourage certain behaviors by reducing overall cost. This research finds that the provision of commuting incentives and subsidies have a significant role in influencing employee commuting choice.

6.1.4.1.1 Free Parking

The provision of parking in cities correlates with increased driving among residents and employees (McCahill et al. 2016). Although McCahill et al. (2016) investigated overall parking and automobile use in nine U.S. cities, their findings confirm the more specific employee commuting results presented in this thesis, which focused on Kendall Square in Cambridge, MA. The analysis conducted as part of this study reveals that employees working at companies that offer free parking choose to commute to work by SOV at significantly higher rates than employees at companies without this benefit.

The provision of free parking is one of the strongest indicators of mode choice and is associated with a higher likelihood of individuals choosing to drive alone, confirming previous findings by Wilson and Shoup (1990) and Jaffe (2016). This statistically significant relationship further supports previous research in Portland, OR (Hess 2001), Cambridge, MA (McCahill and Garrick 2008), Cambridge, UK (Panter, Desousa, and Ogilvie 2013; Knott et al. 2019), and California (Khordagui 2019). Therefore, companies that hope to encourage a more sustainable mode split should introduce incentive programs that promote alternative modes of transportation instead of those that promote the use of personal vehicles. Companies that offer personal vehicle-related incentives within their larger benefits programs should adjust their policies and programs to reflect the true cost of driving, including externalities associated with personal vehicle use, such as congestion and air pollution. By considering the broader implications of SOV trips and incorporating these costs into their benefits programs, companies can work to promote more sustainable commuting modes among their employees.

In addition to the provision of parking, the cost of commuting also plays an important role in influencing commuter mode choice. Therefore, the provision of strong financial incentives and disincentives is an effective approach when attempting to encourage large-scale changes in the way that

people approach commuting (Farkas 2001). In a study of almost 10,000 employees working in the central business district of Portland, OR, researchers found that increasing daily parking costs directly impacted commuting behavior (Hess 2001). When parking fees exceeded \$6 per day, the predicted probability of SOV commuting was lower (46%) than when parking was provided for free (62%). In California, based on the state household travel survey dataset, researchers estimated that a 10% increase in parking costs could correlate with a 1-2% reduced likelihood of driving (Khordagui 2019).

Municipal policies help to shape the broader transportation environment in which employers and employees function. Municipal policies that restrict and reduce parking capacity in cities can help to reduce automobile use and its associated environmental and social costs (McCahill et al. 2016). These policies can also strongly influence the benefits programs offered by employers and the ways employees take advantage of these programs (Brueckner and Franco 2018). Because employer-provided parking directly conflicts with municipal sustainability goals aimed at reducing SOV commuting trips, raising the cost of parking at work sites to reflect the true cost of driving would help lower the rate of solo automobile trips and the associated externalities (Hess 2001).

Cambridge has made a concerted effort to reduce emissions related to motor vehicles by adopting progressive zoning regulations related to parking and transportation. An additional local example is the implementation of parking maximums for new development in certain districts, such as Kendall Square. The MXD Zoning and Kendall Square Urban Renewal Plan (KSURP) Amendment, which the City Council passed in December 2015, lowered and eliminated the parking minimums for residential and commercial development, respectively, and established parking maximums for all land uses (Boston Properties 2017). Because parking minimums are correlated with increased automobile use, these types of parking requirement changes have important implications for shifting travel behavior away from SOV trips (Weinberger 2012; Chester et al. 2015; Lewyn and Schechtman 2014).

6.1.4.1.2 Subsidies for Alternative Modes

Similarly, when employees are provided with public transit subsidies, they are significantly more likely to commute by these modes than by driving alone. These results confirm previous research conducted in New York and New Jersey (Buono et al. 2017), Seattle (Su and Zhou 2012), Atlanta, GA

(Ghimire and Lancelin 2019), the Washington DC region (Hamre and Buehler 2014), and in four Missouri metropolitan areas (Yang et al. 2015). The significant correlation between public transit subsidies and the use of alternative commuting also supports an earlier study of the Fall 2004 Survey of Best Workplaces for Commuters, which was conducted in four metropolitan areas across the country (Denver, CO; Houston, TX; San Francisco, CA; Washington DC). Through this research, the authors found that a significant number of employees take advantage of employer-provided benefits aimed at encouraging the use of alternative modes of transportation (Herzog et al. 2006).

Commuters in the New York-New Jersey region were “about 9 times more likely to ride public transport than to drive alone and 3 times more likely to change their travel behavior towards walking or cycling” when they received public transit-related subsidies, such as monthly passes, vouchers, or reimbursements (Bueno et al. 2017). After providing these benefits, the probability of driving reduced by 16% and the probability of taking public transport increased by 15%. When provided with benefits such as cyclist showers, lockers, or bike parking, employees were 50 times more likely to commute by bicycle compared to those provided with no subsidies (Bueno et al. 2017).

These findings have important implications in advancing sustainability goals because reducing drive-alone trips is directly related to reducing GHG emissions. Benefits packages that include financial incentives in addition to services, such as a guaranteed ride home and carpool matching, and informational campaigns, represent the most effective method in encouraging sustainable mode choices. Compared to benefits packages that offer only services and information, which reduced the traffic and gas emissions by 7%, the inclusion of financial incentives reduced emissions by about 15% (Herzog et al. 2006).

While the results of this thesis indicate a significant difference in commuting behaviors between those provided with incentives and those without, the relatively small effect sizes² of free parking ($\eta^2=0.03$) and transit subsidies ($\eta^2=0.01$) illustrate that there are other factors affecting employees' mode choice.

² Effect size is a statistical measurement that quantifies the strength of the relationship between variables, thereby providing a more comprehensive understanding of the phenomenon of interest. While the p value relies on sample size and indicates if an effect exists, effect size is independent of sample size and indicates the magnitude of the association between the independent and dependent variable (Sullivan and Feinn 2012).

Therefore, these incentives do not represent the main determinant, but one factor of many, a finding that further supports the need for a flexible, comprehensive approach.

6.1.4.1.3 Interaction Between Free Parking and Transit Subsidies

When the provision of free parking and the provision of subsidized transit are considered separately, both have statistically significant impacts on SOV commuting, the former resulting in significantly higher rates of SOVs and the latter resulting in significantly lower SOV rates. When provided together, the provision of free parking becomes the sole statistically significant factor, regardless of the provision of subsidized transit.

These findings suggest that when employees are provided with both driving and alternative transportation subsidies, the former negates the potential positive benefits of receiving transit subsidies, supporting previous research (Hamre and Buehler 2014; Bueno et al. 2017). In a study of 4,630 regular commuters in the Washington DC region, researchers evaluated mode preferences to determine factors that contributed to transportation choice. Providing benefits for walking, cycling, and public transportation corresponded to an increased likelihood of choosing alternatives to driving; however, the inclusion of free parking offset these positive reductions in driving. Their findings reveal that “free parking alone is associated with a 96.6 percent probability to drive alone to work” and “providing free car parking alongside public transportation benefits was not associated with significantly differing odds compared to providing no benefits at all” (Hamre and Buehler 2014). Thus, employer benefits packages are most effective in reducing driving when car parking is not free and that the most viable model is to provide benefits for alternatives to driving, such as transit or vanpooling benefits, showers and lockers, and bike parking.

6.1.4.2 Disincentives

Because personal choices, judgments, and priorities, influence commute choice, many theories of behavioral economics are applicable when studying effective methods for shifting transportation patterns (Garcia-Sierra, van den Bergh, and Miralles-Guasch 2015). Loss aversion is one well-recognized concept in behavioral economics which explains that individuals are often more sensitive to potential losses than to the equivalent potential gains (Kahneman and Tversky 1979). Although an analysis of the impact of

disincentives was not part of this study, disincentives can be effective tools in discouraging certain behaviors or actions (Ott 2018).

According to survey responses, the provision of both free parking and subsidized transit did not encourage reduced rates of SOV commuting. Many respondents also indicated that increases in on-site parking fees would “not likely” discourage them from driving. Eriksson, Nordlund, and Garvill (2010) found that improved public transportation would be more effective in reducing driving than increased automobile-related costs; however, the complementary use of disincentives can still be effective components of a larger program aimed at shifting behavior. Although not a primary deterrent, disincentives could help to counteract the numerous privileges that drivers experience as a result of government investment (Bishop-Henchman 2014; Litman 2020c), public policies and the law (Shill 2019), and land use practices (Shoup 1999; McCahill et al. 2016; Litman 2020a). Policies that include congestion pricing, smart tolling, and prioritizing rideshare and carpool vehicles should be considered as additional methods to disincentivize SOV commuting, all of which represent effective strategies in reducing drive-alone rates (Dennis 2009; Jacobs 2011).

6.1.4.3 Additional Strategies

There are numerous approaches to initiating changes in commuter behavior, beyond subsidies for specific modes of transportation. Although the analysis in this thesis does not consider parking cash-out programs and congestion pricing, the former strategy represents an employer-level incentive and the latter represents a larger, regional-scale disincentive. Both of these additional strategies reduce rates of automobile use for commuting.

6.1.4.3.1 Parking Cash-Out (Rewards for not driving)

The use of parking cash-out programs is an effective incentive strategy to reduce SOV commuting trips by financially encouraging the use of alternative mode choices. This type of incentive program significantly lowers the probability of individuals choosing to commute using a private car and encourages employees to consider alternative forms of transportation (Evangelinos et al. 2018; Shoup 1997).

There are a limited number of practical examples of the implementation of this type of incentive program; however, in 1992 California passed a law requiring certain employers to offer a cash allowance instead of a parking space (California Air Resources Board 2017). In the absence of income taxes, the implementation of a cash-out policy, similar to the one in California, can mitigate the less desirable results associated with employer-provided parking (Brueckner and Franco 2018). This state-mandated policy on SOV commuting was effective in encouraging alternative modes of transportation for 8 employers ranging in size, with SOV commuting and total VMT reduced by 17% and 12%, respectively, transit ridership and walking/bicycling increased by 50% and 33%, respectively, and the average employers' commuting subsidy per employee increasing by only \$2/month (Shoup 1997).

Similarly, the provision of a parking cash-out option significantly lowered the probability of individuals choosing to commute by driving a personal car in Dresden, Germany (Evangelinos et al. 2018) and Dublin, Ireland (Watters, O'Mahony, and Caulfield 2006). Based on survey responses, about one-third of individuals indicated that they would be willing to give up their parking spaces if offered a cash-out policy. Of those employees, 66% indicated a preference to cycle, walk, receive a tax-free public transport ticket, or join a carpool, while the remaining 34% indicated that they would choose to park elsewhere or choose an 'other' option (Watters, O'Mahony, and Caulfield 2006). Interestingly, the probability of accepting any form of cash-out option is negatively correlated with the age of the individual. This has implications for companies with an aging workforce who may be less willing or able to give up driving.

Although cash incentives, such as parking cash-out programs, may be successful in reducing car usage, this may be more beneficial for short term changes, rather than long-term, more permanent behavioral transitions. When studying effective interventions, there is evidence suggesting that desired behavioral changes cease once the incentive ends (Graham-Rowe et al. 2011). This limitation supports previous behavioral economic research that cautions the use of extrinsic incentives when trying to change lifestyle habits (Rey-Biel, Gneezy, and Meier 2011). Because human behavior is complex, there are varying opinions regarding the effectiveness of providing incentives. While Rey-Biel, Gneezy, and Meier (2011) mention the risk of the extrinsic incentive reducing an individual's intrinsic motivation, they also acknowledge that short-term changes can be valuable. Although the incentives may be temporary, they may provide an opportunity for individuals to rethink their commutes and try alternative options of which they

may not have previously been aware. In a study of drivers provided with a free transit pass, the majority (70%) continued to use transit after the end of the 3-month trial, choosing to purchase a discounted pass instead of regaining their parking permits (Gould and Zhou 2010). Because of the diverse needs of employees and the potential limitations of extrinsic incentives, cash-out options represent an effective method in reducing car use if integrated into a larger package of transportation demand measures (Watters, O'Mahony, and Caulfield 2006).

6.1.4.3.2 Congestion Pricing

Congestion pricing refers to a system that imposes fees for using specific roads or entering a designated area, with the goals of regulating travel demand, reducing pollution, lowering congestion, and generating revenue for transportation projects (Bhatt and Higgins 2008; Federal Highway Administration 2020). Implementing these systems requires substantial investment in the form of creating supportive policies, initiating and continuing active public engagement, and developing the required technological infrastructure for administration and enforcement. Although congestion pricing programs require years of preparation and outreach, the long-term health and financial benefits far outweigh the initial costs and continued maintenance (Bhatt and Higgins 2008; Yu et al. 2019; Anas and Lindsey 2011). In addition, researchers in Germany determined that road pricing can be more effective in reducing the negative externalities associated with driving alone when compared to the use of parking space fees (Evangelinos et al. 2018).

Despite the many benefits associated with successful programs, implementing them can be challenging from a public policy standpoint because of concerns regarding equity and the difficulty of garnering public acceptance and approval (Anas and Lindsey 2011; Bhatt and Higgins 2008; "Seattle Congestion Pricing Study: Phase 1 Summary Report" 2019). This is especially true for cities in the United States where the general response tends to be negative (Anas and Lindsey 2011; Harrington, Krupnick, and Alberini 1998; Marshall 2019). After studying downtown congestion pricing systems in five international cities (Singapore, London, Stockholm, Milan, and Gothenburg), Lehe (2019) concluded that a political catalyst was a common reason for their implementation. And although initially unpopular in many of these cities, congestion pricing often gains support over time largely because people can personally observe and

experience the benefits (Domonoske 2019). Since their implementation, these five international systems have aided in the reduction of vehicle trips, GHG emissions, and travel time, while also generating millions in annual net revenue (“Seattle Congestion Pricing Study: Phase 1 Summary Report” 2019).

In 2021, New York City plans to implement the next phase of its congestion pricing plan, which would make it the first urban area in the United States to impose this form of system (Hu 2019; Berger 2020). Other cities around the country, such as Los Angeles, Portland, OR, San Francisco, and Seattle, are also conducting studies to identify the benefits and challenges to implementation (“Seattle Congestion Pricing Study: Phase 1 Summary Report” 2019). Because these types of pricing programs were successfully introduced in other parts of the world, such as many countries in Europe and Southeast Asia, there are numerous examples and lessons to be learned in planning and designing congestion pricing schemes, accommodating the needs of different populations, and achieving the desired results (Bhatt and Higgins 2008).

Because congestion pricing includes a wide variety of practices, these systems are often uniquely configured to fit the physical, economic, and social environment of the region in which they are implemented (Lehe 2019). The willingness of residents to support these systems largely depends on their personal awareness and perceptions regarding the proposed policies. Because increased familiarity often results in higher rates of acceptance, introducing this type of system requires thoughtful planning and public engagement efforts that promote effective communication and accurate information sharing (Harrington, Krupnick, and Alberini 1998; Milenković, Glavić, and Maričić 2019).

6.1.4.4 Balancing Incentives with Disincentives

Balancing incentives that make alternatives more attractive to users, with disincentives that discourage automobile use, is one of the most effective strategies in inspiring significant mode shifts. Based on policy scenario tests in Berkeley, individual policies resulted in modest shifts while paired policies, in which parking prices were increased and transit was subsidized, initiated more significant changes in behavior (Proulx, Cavagnolo, and Torres-Montoya 2014). This outcome confirms previous case studies in Portland, OR (Peng, Dueker, and Strathman 1996), London (Metz 2015), Cambridge, UK (Panter et al. 2013), Bristol, UK (Brockman and Fox 2011), Baltimore and Philadelphia (Farkas 2001), Perth, Australia

(Petrunoff et al. 2015), and Växjö, Sweden (Eriksson, Nordlund, and Garvill 2010). A literature review of 14 case study cities primarily located in the United States and Europe supported the effectiveness of packages including complementary, paired interventions (Pucher, Dill, and Handy 2010). In this study, the authors concluded that pairing pro-bicycle programs and bicycling infrastructure with restrictions on car use, along with other interventions, resulted in significantly increased bicycle use.

Among commuters in the New York and New Jersey region, car ownership, public transportation subsidies, and access to the public transportation network had an overall greater influence on commute mode choice, when compared to personal and household characteristics (Bueno et al. 2017). When studying commuter behavior in London, Metz (2015) found that the combination of interventions targeted at improving public transit efficiency and placing constraints on cars provided the most effective policy strategies for reducing congestion in urban centers.

Based on studies in Cambridge, UK and Seattle, WA, limiting or charging for workplace parking and making alternative modes of transportation (biking, walking, public transit, carpooling) more convenient represent two of the greatest predictors in influencing a mode shift toward active commuting (Panter et al. 2013; Panter, Desousa, and Ogilvie 2013; Su and Zhou 2012). Eriksson, Nordlund, and Garvill (2010) have reasoned that these findings are likely because of financial considerations - as the cost of commuting by SOV increases because of higher parking- or driving-related costs, the cost of utilizing alternative modes of transportation decreases because of subsidies and improved service. Because cost is one of the predominant factors in inspiring modal shifts and reducing GHG emissions, combined measures that shift the cost burden away from public transit help to make sustainable commuting modes more attractive than implementing isolated policies (Conti 2018; Eriksson, Nordlund, and Garvill 2010; Washbrook, Haider, and Jaccard 2006).

To ensure that the infrastructure and capacity of the alternative systems can support intended behavioral shifts, interventions need to be implemented strategically. A large number of survey responses studied in this thesis research cited transportation infrastructure as a major limitation of the current system when asked what would encourage them to switch from driving alone to another mode. Improving the service, reliability, and convenience of alternative transportation modes has the potential to increase ridership and lower SOV commuting. In addition, those reporting supportive environments for walking and

cycling are more likely to supplement their commutes with these forms of travel (Panter, Desousa, and Ogilvie 2013). Thus, pairing these service and infrastructural improvements with simultaneous measures that makes commuters more aware of the costs associated with driving alone represents the most effective strategy in reducing SOV rates among commuters (Eriksson, Nordlund, and Garvill 2010).

When working to initiate behavioral change at a regional-scale, it is also important to consider the consequences on populations who are more heavily reliant on their automobiles because of personal commitments, physical limitations, or geographic challenges. Increasing the cost of driving would result in fewer SOV commuters; however, without providing viable and realistic alternatives, low-wage workers who are the least able to absorb these increased costs would likely be disproportionately burdened. Because these types of policies have social consequences and can impact populations differently, it is important for planning and policy making to consider the needs of diverse populations and provide adequate options when trying to create a more sustainable and equitable transportation system (Farkas 2001; Conti 2018).

6.1.5 Increasing Awareness

The results of this analysis illustrate that many employees are unsure or misinformed about their company's benefits and commuting incentives, a finding that supplements a study of commuters at UC Berkeley (Riggs and Kuo 2015). When employers are trying to encourage the use of alternative commuting modes, an employee's lack of knowledge regarding the company commuting policies and programs can be a significant barrier to achieving this goal. Employers can overcome this challenge by creating effective marketing campaigns. This form of outreach is a relatively simple and low-cost solution with the potential for high returns in the form of more sustainable employee mode splits.

The TransAction surveys asked both employers and employees whether transit information is made available in central locations. The employees at companies that do report posting schedules are more aware of the availability of on-site information than the employees at companies that do not post transit schedules; however, even when information is available to employees, there are varying degrees of awareness. The availability of this information may be beneficial for employees who are already interested in considering public transportation as a commuting option; however, the presence of a schedule or

information is unlikely to facilitate a widespread shift among employees who are unfamiliar with the service.

6.1.5.1 Employer Involvement

One effective way to increase awareness of transportation benefits and encourage employees to reconsider their commuting habits is for employers to dedicate time and resources to engage actively with their employees. Buy in and leadership from the top is crucial when trying to encourage a behavioral shift. In a meeting with an employee from the MBTA about Perq (formerly the MBTA's Corporate Pass Program), they discussed the creation and dispersal of a simple flyer introducing the program. In addition to providing information passively, the flyer provides an opportunity for employers to initiate a conversation with their employees, which may lead to continued discussion.

According to this MBTA employee, there are four general times when people are most likely to rethink their commute - a residential or office move, the start of a new job, and when a company introduces commuting benefits programs through rollout events (MBTA Employee 2020). Because moving houses and changing jobs are often personal choices, office relocations and company marketing activities provide opportunities for employers to get their employees to think about their commuting patterns and potential alternatives. This supports previous research of the UK Household Longitudinal Study, which reveals that changes in the distance between home and work were the primary driver of commute mode changes (B. Clark, Chatterjee, and Melia 2016).

After moving offices, one Boston company decided to schedule time to meet with employees to discuss their commuting choices. Although the idea of setting aside time to host individual conversations is relatively simple, it required company investment of time and personnel. By hosting individual consultations, employers encouraged their employees to reevaluate their habits. This employer's effort and engagement was successful in reducing parking utilization by 50%, illustrating the value of dedicating time to discuss and reconsider alternatives at an individual level. Because many commuters choose their mode out of habit, this type of employer initiative demonstrates the company's commitment to pursuing a more sustainable mode split by engaging with their employees.

6.1.5.2 Media Campaigns and Messaging

The use of media campaigns is an effective way to achieve more sustainable commuting behavior, especially when paired with additional interventions (Scheepers et al. 2014). Because an individual's commuting decisions are largely made based on a combination of factors, such as personal values, priorities, and responsibilities, targeted outreach provides a way to personalize the message and encourage a change in established habits. When studying drivers on UC Berkeley's campus, researchers found that a targeted outreach campaign that included customized messages was effective in causing a shift in travel behavior away from driving alone (Riggs and Kuo 2015). The ability to effectively communicate with different groups of people, all of whom have different backgrounds and experiences, requires an understanding of the factors that influence their decision-making process. For example, in a study investigating commuter cyclists in Victoria, Australia, researchers found that two of the highest motivating factors influencing commuters to cycle to work were health benefits and environmental consciousness (Ahmed, Rose, and Jakob 2013). Based on these results, efforts to increase sustainable commuting behavior within the Greater Boston area would likely be more successful if outreach strategies could be customized to local demographic characteristics and emphasize employees' motivating factors. Unfortunately for this thesis research, the TransAction survey asked respondents to provide their reasons for taking alternative modes collectively, limiting the power to correlate specific mode choices with specific motivators.

An employee's experience, education, and social circumstances significantly influence commute choices (Habibian and Kermanshah 2013; Ye and Titheridge 2017). Thus, it is important for employers to design their strategies and outreach efforts to account for the different perspectives of their employees. The following two examples illustrate the complex relationship between personal characteristics and transportation choices.

While age has a significant impact on travel choices (Hayden, Tight, and Burrow 2017; Ye and Titheridge 2017), many studies reveal conflicting results associating different age groups with specific types of transportation. Although younger individuals are more likely to use alternative transportation modes (Lind et al. 2015; Ding et al. 2017) and middle-aged individuals are more likely to commute by car (Ding et al. 2017), these sources present incompatible results regarding elderly populations and their transportation preferences - by personal vehicle (Lind et al. 2015) or alternative modes (Ding et al. 2017).

Because of the additional factors that are related to age and contribute to mode choice, such as physical mobility limitations, financial stability, and housing locations, it can be difficult to generalize the preferences of large groups of people living in a range of communities.

Education and income levels are also difficult to correlate with transportation uses because these factors are closely related to other socio-demographic characteristics, such as housing opportunities, residential location, and access to services and amenities. While some studies report that individuals with higher education levels and household incomes more frequently commute by SOV (Schwanen and Mokhtarian 2005; Ding et al. 2017; Ye and Titheridge 2017), others conclude that higher annual income correlates with increased rates of public and active transportation (Lind et al. 2015). To explain these different findings, Ding et al. (2017) proposed that because individuals with higher incomes often work in the central business district, they “are involved in a longer distance for work and social activities, which will increase the probability of driving.” Lind et al. (2015) provide an alternative explanation indicating that those with higher incomes can afford to live in city centers near their workplace where property is more expensive, therefore reducing their need to drive. The choice of public transit mode also varies between socioeconomic and educational status. For individuals with lower income and lower education levels, some studies reveal that they are more likely to drive (Lind et al. 2015), while others indicate that they are more likely to depend on public transportation (Ding et al. 2017). The different forms of public transportation correlate with varying income and educational levels - those with lower incomes and less education more often rely on city buses, while individuals with higher income and educational attainment use subway or rail systems more often (Tajalli and Hajbabaie 2017). This supports previous research which shows that more affluent areas often have better access to rail options (H. M. Clark 2017), further highlighting the relationship between property values and proximity to transit (Gorey 2019).

Overall, understanding the large range of factors that influence commute mode decisions can help to establish a baseline for employers who are trying to reexamine their commuting policies and programs. Researchers have studied additional factors impacting mode choice, such as gender and family structure, with conflicting results (St-Louis et al. 2014; Wang et al. 2013; Lind et al. 2015; Ding et al. 2017; Panter et al. 2013). To create an effective strategy with the goal of a more sustainable mode split, employers should apply their general understanding of socio-demographic trends and supplement it with their understanding

of their workforce. In this way, they can benefit from the available research, while also addressing the commuting needs and concerns of their employees. Because demographic characteristics vary regionally and within companies, developing familiarity and awareness requires employers to be willing to invest in their employees and understand how personal and external circumstances can influence transportation choices.

In summary, employers have an important role in influencing employee commuting behavior by taking an active interest in encouraging more sustainable travel modes and by introducing thoughtful benefits packages. Allowing for more flexibility, making sustainable commuting options easier and more convenient for employees, and increasing outreach and marketing strategies are three effective methods for shifting employee mode split away from SOV commuting. It is important to note that the amount of personal effort required to overcome the barriers identified by participants ranges greatly, and in some cases may not be achievable with changes made at the individual or even at the company level. To support and ensure the success of smaller-scale measures, employers need to implement programs that are functional within the larger transportation system. Achieving a large-scale shift in commuting patterns requires employers to approach their commuting benefits programs from a comprehensive perspective.

6.2 Beyond Employers

6.2.1 Systems Approach

The goal of achieving a more sustainable mode split at a larger scale must be considered and approached holistically. Instead of viewing the high rates of SOV commuting as separate issues at the employee, employer, government, or infrastructural levels, addressing complex transportation challenges requires more comprehensive planning and coordinated efforts. The most successful efforts that will bring about widespread shifts in commuting behavior will require a systems-level framework.

When multiple measures are combined and introduced as part of a coordinated effort, the results can have a much greater impact than the sum of individually implemented efforts (Zhang, Fujii, and Managi 2014a; Pucher, Dill, and Handy 2010; Eriksson, Nordlund, and Garvill 2010; Scheepers et al. 2014). Combined TDM measures lead to larger behavioral responses in comparison to the implementation of individual measures (Eriksson, Nordlund, and Garvill 2010). For example, bicycling infrastructure is an

important factor in encouraging mode shifts and increasing rates of bicycling commuting, yet it has an even greater impact when integrated into a comprehensive package of interventions, including complementary programs and policies (Pucher, Dill, and Handy 2010).

Familiarity with the way the system functions allows stakeholders, such as municipalities and employers, to prioritize and advocate for measures that optimize system performance and supplement gaps in service. As Chakrabarti (2017) recommended, “it is critical to invest in the right dimensions of service at the right places.” Because funds are often limited for transportation improvements, thoughtful investment requires prioritizing the projects that maximize service quality. Understanding the way different aspects of service interact allows decision-makers to allocate resources to projects that will increase ridership, service, and accessibility for current and potential users, especially populations that are often underserved. Strategic decision making and targeted investment that attempts to account for all of the challenges and range of outcomes have the most potential to achieve long-term success in increasing sustainable transportation behavior.

Strategic investment decisions in transit improvements and the adoption of supportive policies are two important components of trying to influence mode shifts at a large scale. Understanding the transportation system as a whole requires a familiarity with the location and the neighborhoods beyond the immediate transit station areas (Vaccaro 2019; Guthrie and Fan 2016). The spatial component is important to consider because transit system ridership is dependent on the larger region in which the system functions. While targeting investment towards priority stations and neighborhoods can help to increase accessibility and achieve higher rates of ridership, accounting for the needs of passengers is another critical component of creating a successful and cohesive system. Having the knowledge of and familiarity with specific communities and neighborhoods can help decision-makers anticipate challenges that different communities of users may encounter when deciding between transportation modes. Taking into account and accommodating these diverse needs further ensures that investments and resources are used efficiently to lower potential barriers and provide comprehensive service to all individuals. An additional way familiarity with the system can help to create a more inclusive transit system includes an understanding of the current policies that regulate land use and development patterns (Ambarwati et al. 2016).

Understanding the environment in which the system is functioning and the factors influencing urban

structure can help shape future policy and legislative modifications to support more sustainable transportation choices.

While this thesis research focuses on the geographic region of Kendall Square in Cambridge, employers and employees at these businesses rely on the MBTA and regional transportation system as a whole. Therefore, transit infrastructure challenges extend beyond Cambridge's jurisdiction and are largely dependent on the larger regional and state financial, political, socio-cultural, and technological environments. Because transportation intersects sectors and industries, achieving a more sustainable mode split requires collaboration and the formation of strong partnerships among the various stakeholders.

6.2.2 Transit Improvements

Based on the employee survey responses, the most frequently cited improvement that would encourage a mode shift is improved public transit. Because this request is out of individual employers' direct control, encouraging a switch from SOV commuting to alternative modes of transportation will require improvements to the existing transportation system. Although these improvements can be organized into two main categories - physical infrastructure improvements and service-related improvements - it is important to consider the system comprehensively. Because the transit system is a network of interdependent transit operations that are heavily reliant on the political, economic, and social environment of the region, improvements should be considered at the systems level.

6.2.2.1 Infrastructure

6.2.2.1.1 Public Transportation

According to the 2017 Infrastructure Report Card, published by the American Society of Civil Engineers (ASCE), the country's transit infrastructure received the lowest grade of all 16 infrastructure categories. The ASCE defines this low grade (D-) as infrastructure that is "poor to fair condition and mostly below standard, with many elements approaching the end of their service life." Because transit is chronically underfunded, the ASCE found that the system "exhibits significant deterioration." Based on these findings, federal estimates quantify backlogged maintenance and rehabilitation to equal about \$90 billion to achieve a "state of good repair" ("2017 Infrastructure Report Card" 2017).

Municipalities across the country are experiencing challenges resulting from underinvestment and backlogged maintenance. Beyond financial concerns, the MBTA faces additional challenges, one of which being the system's age. The MBTA operates the oldest subway system in the country, with parts of the tunnel sections dating back to the late 19th century (Massachusetts Bay Transportation Authority 2017). In addition to an old system and design, the average ages of MBTA transit vehicles are older than the national averages, especially for light rail vehicles (24.7y vs. 18.5y) and trolleybuses (13.0y vs. 9.8y) ("Transit Profiles 2017 Top 50 Summary" 2018; Bureau of Transportation Statistics 2018). Within the study area of Kendall Square, compounding financial concerns have led to an inability to meet current bus demand and "an antiquated Red Line signal system that limits the frequency of subway trains" (Moskowitz 2012).

Ideally, improvements to the existing transit system would include the expansion and enhancement of service across the region, which would help to retain and attract riders. However, due to limited funding and resources, many transit agencies are preoccupied with acquiring the funding necessary for routine maintenance and repairs to keep the existing system functioning. Without addressing these infrastructural challenges, service quality will continue to deteriorate which will have negative impacts on ridership and revenue. This constant search for financial support prevents many transit agencies from being able to devote resources to considering and pursuing longer-term goals.

Because transportation funding is the responsibility of the federal, state, and local governments, Eric Bourassa, the Director of the Transportation Division at MAPC, identified the political environment as the largest challenge to implementing a more sustainable mode split among employees (Bourassa 2020). Ms. Westwater at KSA indicated that the political climate has the potential to positively impact commuters and employers by refocusing priorities and opening opportunities for future projects (Westwater 2020). In early March 2020, the Massachusetts House of Representatives passed two transportation-related bills - a revenue package (H.4508) (An Act Relative to Transportation Finance) and a bond bill (H.4506) (An Act Authorizing and Accelerating Transportation Investment). The purposes of these bills are to generate revenue for improving the transportation system by raising taxes and fees and to authorize spending on transportation projects, respectively (Schoenberg 2020; Harmon 2020; Lisinski, Norton, and Murphy 2020). Although many stakeholders feel that these bills are encouraging and represent a first step, they also feel that these legislative efforts are not strong enough to adequately address the limitations of the current

system (Tao 2020; Murphy and Lisinski 2020). Mr. Bourassa at MAPC believes that this new legislation could have modest impacts on commuters if passed by the Senate (Bourassa 2020). To counteract political barriers, Ms. Groll, the Parking and Transportation Demand Management Planning Officer at Cambridge's CDD, emphasized the importance of remaining persistent in setting and pursuing ambitious goals (Groll 2020).

6.2.2.1.2 Active Transportation

Improvements in active transportation infrastructure are also important when trying to encourage large-scale mode shifts away from SOV commuting. When environments and infrastructure are supportive of alternative modes of transportation, people are more likely to walk, bike, or use public transit (Panter et al. 2016; Andersen 2016; Sallis et al. 2016; Zahabi et al. 2016). Also, exposure to transit and pedestrian-friendly environments is associated with changing attitudes and perceptions regarding these alternative transportation modes (Panter et al. 2013). These findings have important implications for reducing the use of personal vehicles. Because people prefer to act in ways that are consistent with their attitudes or beliefs, more favorable attitudes toward public transportation can result in higher rates of ridership. Therefore, the installation and funding of infrastructure that promotes alternative modes of transportation can have a multiplier effect by encouraging increased use and more favorable attitudes. These can ultimately inspire more economic, political, and cultural support for plans and policies that advance these forms of transportation.

To promote biking as a commuting option, the physical infrastructure should support the needs of all potential users. Inadequate cycling infrastructure, unsafe conditions, and topography challenges represent substantial obstacles that may deter capable individuals from choosing to commute by bike. To account for and mitigate these types of barriers, municipalities and agencies can adopt measures that prioritize safety, efficiency, and comfort. Prioritizing road infrastructure improvements represents one effective strategy to increase the number of bicycle commuters (de Sousa, Sanches, and Ferreira 2014).

Taking comfort levels into account is an important component of designing more inclusive systems because attitudes vary between different types of cyclists (Fernández-Heredia, Monzón, and Jara-Díaz 2014). While more frequent cyclists prioritize efficiency and flexibility and minimize perceived risk,

other users who have less experience prefer safer routes (Caulfield, Brick, and McCarthy 2012). There are numerous road treatments that cater to different proficiency and experience levels and are most suitable for the surrounding traffic patterns. Considerations such as preferences for facilities separated from traffic (Caulfield, Brick, and McCarthy 2012), investments in end-of-trip facilities (Ahmed, Rose, and Jakob 2013), and route quality and connectivity (Piatkowski and Marshall 2015), can increase commuter cycling.

One example of successful cycling infrastructure is the Wiggle, a one-mile biking route connecting Market Street in downtown San Francisco and Golden Gate Park. This path zig-zags along streets purposely chosen to avoid the steep inclines. As a result of user-friendly additions, such as painted green sharrows and wayfinding signs, this route has become popular among diverse groups of cyclists and pedestrians (Li 2015; Nevius 2011). The Wiggle had an unofficial history as a bikeway since the 1970s, but in the 1990s, part of the route was converted to San Francisco's first dedicated bikeway (Gentile 2019). Following this, and after pressure from the San Francisco Bicycle Coalition and tactical urbanism events, the City began adding infrastructure improvements to the route to make it a safer, established route for cyclists. Because of engaged residents and a receptive transit agency, the evolution of this route highlights the gradual shift in thinking about commuting by alternative modes and the importance of accommodating all users (Nevius 2011). This collaborative effort arose because of an expressed desire for better cycling infrastructure and the willingness of the San Francisco Municipal Transportation Authority (SFMTA) to respond. SFMTA continues to complete projects along the Wiggle, recently completing one with the goal of increasing comfort and safety for those living, working, and recreating along this well-used route (wiggle neighborhood green corridor).

The success of this example can be attributed to collaboration and the comprehensive approach that SFMTA adopted. Instead of adding individual interventions, which may have resulted in small increases in cycling rates, SFMTA implemented a combination of complementary traffic calming measures to further the safety and comfort of users along this route. These more comprehensive strategies, which include multiple complementary measures, are often more effective in attracting cycle commuters than isolated improvements (Pucher, Dill, and Handy 2010; de Sousa, Sanches, and Ferreira 2014).

Although the built environment and physical infrastructure influence comfort and increase rates of alternative commuting, general attitudes and perceptions of commuting modes also play a role in commute

choice (Piatkowski and Marshall 2015). Therefore, marketing and outreach should emphasize the additional health and environmental benefits of cycling, in addition to the safety and convenience gained by physical infrastructure improvements (Ahmed, Rose, and Jakob 2013).

6.2.2.2 Service

Enhancing rider experience by improving transit service is one of the most important factors influencing transit use. Although transit agencies are responsible for providing high-quality transit service, they must work within the greater transit environment. As a result, many external factors influence transit agencies' ability to adequately provide appropriate service for their customers. Among the many components that impact rider experience, survey respondents identified three important service considerations that are effective in attracting and retaining riders.

6.2.2.2.1 Reliability and Frequency

An improved public transportation system was the most frequently mentioned change that would encourage employees to consider switching from driving alone to another commuting mode. Survey participants identified improvements such as reliability and frequency of service as the most important, supporting previous research that found a significant positive correlation between service reliability and increases in patronage (Chakrabarti and Giuliano 2015). Some of the ways transit agencies are trying to address these concerns include general strategies such as optimizing headways, service frequency, route configuration, streamlining and simplifying payment options, and coordination among the different modes.

Because public transportation networks rely on numerous interdependent transit services and operations, they should be coordinated using a systems-level approach. Ensuring that all modes work together is important because data compiled from onboard surveys in a 2007 study found that approximately 40% of public transportation trips include at least one transfer between transit vehicles (Neff and Pham 2007). This report also calculated an average transfer ratio of 1.5, meaning that the average passenger utilizes 1.5 transit vehicles during an average trip. Therefore, coordination among modes to reduce the amount of waiting time required for transfers is one way for transit agencies to improve rider experience and satisfaction.

Although it is valuable to look at the ways the system is functioning as a whole, improving bus service is especially important because bus networks often service larger geographic areas and more diverse, lower-income populations - the groups who are more often reliant on public transportation (Lindsey 1971; Andersen 2016; Hughes-Cromwich et al. 2019). In addition, many regional transit agencies must rely solely on bus networks because the infrastructure required for light rail or subway systems is not economically feasible and the population density is not sufficient to support the investment (Hubner 2015; Rode and Floater 2014). Due to these considerations, there are over 1,000 bus systems in service around the country, and fewer than 30 commuter rail, heavy rail, light rail, or streetcar systems (Hughes-Cromwich et al. 2020).

There is a general perception that transit users prefer light rail and subway systems over buses because they can provide higher quality service. In terms of travel time, the dedicated lanes of the former modes are often more efficient than the latter, which often share the road with personal cars and other vehicles. In Germany, researchers found that survey respondents largely prefer rail because of a “psychological rail factor,” which is heavily influenced by “emotional and social attributions” (Scherer and Dziekan 2012). Despite this finding, case studies in Washington DC and Boston revealed that there is little preference between rail or bus when service quality, measured by cost and time, is comparable (Ben-Akiva, 2002). Similarly, researchers in Australia found that travel time is the most important factor motivating individuals’ commuting choices (Anwar and Yang 2017).

Because of the flexibility and lower costs of buses and their associated infrastructure, many transit agencies and cities are choosing to prioritize bus service improvements to increase ridership (“There’s a Reason Transit Ridership Is Rising in These 7 Cities” 2019). One way of accomplishing this is through the implementation of bus rapid transit (BRT), a system that includes innovative features such as dedicated right-of-way, transit signal priority (TSP) strategies, off-board fare collection, enhanced station design and amenities, and more frequent service. These strategies have the potential to increase ridership and reduce car dependency. A study of Chicago commuting patterns found that mode shifts to transit are most likely when driving conditions are unreliable and transit systems are competitive in terms of travel time (Sweet and Chen 2011). In addition to general bus service improvements, the introduction of BRT systems results in increased ridership rates (Williams 2019; “Richmond’s Transit Revolution: GRTC Ridership and

Accessibility Analysis” 2019; Tann et al. 2010; Panero et al. 2012), improved accessibility (Bertolaccini 2018; “Richmond’s Transit Revolution: GRTC Ridership and Accessibility Analysis” 2019; Panero et al. 2012), reduced or competitive travel times (Tann et al. 2010; Panero et al. 2012), and lower CO2 emissions (Vincent and Jerram 2006; McDonnell, Ferreira, and Convery 2008; Hughes and Zhu 2011).

BRT represents just one way cities and transit agencies are approaching the widespread issues of frequency and reliability. In many urban areas, a variety of measures targeting other modes are being introduced to improve the transportation network as a whole. Cities around the country are in the proposal, planning, or construction phases of service extensions to their light rail systems (including Boston, Dallas, Denver, Los Angeles, Phoenix, and Seattle), commuter train systems (including Boston, New York City, San Francisco, Seattle, and Washington D.C.), and ferry systems (including New York City and San Francisco).

6.2.2.2.2 Transit Accessibility

While increasing the reliability and frequency of transit services can help to improve satisfaction with the system and increase ridership, these considerations have little impact on influencing the mode choice of individuals who are unable to access the system due to geographic or mobility constraints. Therefore, a higher level of public transit accessibility is a complementary component of an efficient transportation system and should be considered when implementing a mode shift away from SOVs. Beyond attracting new riders and retaining the patronage of current riders, improved public transportation access is crucial because it extends service to underserved neighborhoods and transit-dependent populations (Chakrabarti 2017).

Based on survey responses, increases in access to transit are correlated with increases in the use of alternative commuting modes and decreases in the rates of SOV commuting, a finding which supports previous research in Xi’an, China (Ye and Titheridge 2017) and four Missouri metropolitan areas (Yang et al. 2015). This result indicates that the location and the capacity of the physical infrastructure of transit stations are important considerations when trying to encourage a mode shift and creating the potential to improve mode splits.

Survey participants identified the need for increased accessibility as a challenge in shifting away from SOV commuting, a finding further supported by The Boston Globe's 2019 Spotlight series, "Seeing Red" (Vaccaro and Ostriker 2019). Parking availability at the commuter rail and terminal transit stations is one way the capacity of the physical infrastructure is currently limiting transit accessibility. Because many commuters may be averse to taking risks, the uncertainty of being able to find a parking space has a direct impact on their willingness to consider alternative modes of transportation. The MBTA represents one of many landowners that manage the parking lots and garages near transit stations. 70 percent of spaces across the parking system are filled on weekday mornings and "about one-third of lots owned by the T are at least 90 percent full on a typical day" (Vaccaro 2019). Therefore, added parking could be beneficial in reducing drive-alone rates and VMT by making public transportation more accessible for individuals who live in areas farther outside of the transportation network.

As with all recommendations and measures, impacts on the larger system must be considered. This issue is particularly challenging because the scarcity of parking is not a uniform issue across the system. Instead, there is variation in parking availability with some lots at capacity by early morning, and some remaining below capacity throughout the day. Therefore, while adding parking may be beneficial at certain stations, it is not a simple fix that can be applied throughout the network. According to the article "One big barrier to MBTA ridership? Not enough space for cars," the MBTA is adjusting prices to "divert riders to open lots and relieve the crowded ones" as one approach to addressing limited parking availability (Vaccaro 2019). By considering the system as a whole, this approach is a cost-effective strategy in which commuters are incentivized to optimize the existing infrastructure without requiring large infrastructure investments.

While parking capacity is the immediate issue presented in The Boston Globe article, the broader, larger-scale issues of transit accessibility, as well as the first and last-mile connections require consideration as well. Building additional parking spaces may increase the rates of public transit in the short term, but it also has the potential to undermine other efforts to reduce SOV commuting, such as transit-oriented development (TOD).

Overall, this difficulty in finding parking and accessing transit stations illustrates the importance of optimizing all transportation modes that comprise the system. Because the barriers to extending

accessibility vary between municipalities, improvement measures need to be tailored to fit the specific conditions limiting transit accessibility. To inspire commuting shifts toward more sustainable modes, transit agencies, policymakers, and planners need to allocate resources and coordinate complementary efforts, such as augmenting car parking, redesigning service routes, and supporting efforts that will make it easier and safer for commuters to walk or bike.

6.2.2.2.3 Amenities

In addition to transit service improvements, amenities are supplemental components that can enhance rider experience and increase sustainable commuting rates. When the TransAction survey asked participants to provide open-ended responses to explain their reasons for taking alternative forms of transportation, many mentioned that they enjoyed being able to use their commuting time for work-related or leisure activities. Based on this finding, transit authorities can play an important role in increasing satisfaction with service and increasing ridership by making public transit options more enjoyable and “designing commuter experiences that permit productivity” (Kent de Grey, Werner, and Lilja Lohnes 2018).

Providing and enhancing amenities are correlated with increases in ridership numbers and satisfaction among riders (Higashide 2016). These improvements can include measures such as real-time transit information systems (Tang and Thakuriah 2012; Brakewood, Macfarlane, and Watkins 2015; Fortunati 2018), enhanced transit stop shelters (Kim, Bartholomew, and Ewing 2018; Eo 2018; Buchanan and Hovenkotter 2018), safety and security measures (Ingalls, Hartgen, and Owens 1994; M. J. Smith 2008; Perk, Flynn, and Volinski 2008), convenient payment options (Quibria 2008; Donner 2019), and more supplemental perks like WiFi (Taylo 2013; Zhang, Fujii, and Managi 2014b).

Although these types of added amenities are appreciated and may attract some users, when respondents chose from survey-provided options, convenience, cost, and time were the most important considerations when deciding to utilize alternative commuting modes. The findings from this thesis analysis confirm transit users’ tendency to prioritize service reliability and quality over added perks such as WiFi and power outlets (Higashide 2016). In this TransitCenter study, survey participants ranked time

efficiency, bus headways, and reductions in fare costs as the top three important service improvements, followed by stop and station facilities, real-time transit information, and reducing the number of transfers.

While amenities and comfort may not be the highest priority for transit agencies, supplementing the more fundamental transit services (frequency, reliability, and accessibility) with these secondary services helps to improve overall quality. Considering the comfort and customer experience of all transit users, especially transit-reliant individuals, is beneficial from a social equity standpoint by providing viable alternatives to personal vehicle travel. Providing these additional features can help to provide transit users with more positive experiences, thereby improving customer satisfaction with transit and increasing overall ridership by retaining current customers and attracting potential customers (Watkins et al. 2011; Watkins and Brakewood 2016; Higashide and Buchanan 2019).

6.2.3 Policy

Policies are an important component of comprehensive and forward-thinking planning because they establish priorities, protocols, and evaluation measures. Through the process of creating and implementing policies, officials and leaders are provided with the opportunity to guide thoughtful and strategic decision making. Policies are especially beneficial when working at large scales to implement programs that have the potential to impact large numbers of people. The health of the transportation system has widespread impacts on the ways people interact and move throughout space. Therefore, it is important to understand the ways current policies are governing the transportation system and the ways these may be enhanced to achieve a desirable outcome.

6.2.3.1 Cooperation and Coordination

Improving aspects of the regional transportation network require a large-scale perspective that considers the many interdependent components of the system. To successfully implement strategies that work cohesively and achieve increased rates of sustainable commuting, coordination and collaboration among the various stakeholders and communities are vital. Improvements to the transit system and changes in personal commitments are two of the three most frequently cited open-ended responses when respondents were explaining factors that would cause them to shift from SOV commuting to alternative

modes. Because all of these are outside of the direct responsibility and jurisdiction of the individual companies, these changes would require much more coordination across sectors and agencies.

The regional transportation network comprises many interdependent components, all of which must be considered. Because of the complexity inherent in trying to shift the transportation patterns of thousands of employees commuting to an already dense, urban center, “the key is implementing such policies on a broad enough, regional scale to achieve the desired broad, regional impacts” (Guthrie and Fan 2016). To implement successful policies, Guthrie and Fan (2016) suggest the need for “a great deal of regional cooperation and political will.” In the case of encouraging commuting shifts, effective policy making should involve all of the stakeholders who have the potential to be impacted. When the needs of all actors are considered and everyone is provided with an opportunity to contribute, individuals are often more willing to support and adhere to the policies because they are perceived as fair (Garcia-Sierra, van den Bergh, and Miralles-Guasch 2015).

Ms. Groll explained that coordination across communities is one of the most successful ways to ensure the success of transportation-related policies (Groll 2020). As part of her role at CDD, she ensures that Cambridge is working with the business community to achieve their overall goals of promoting safe and sustainable transportation-related behavior, while also encouraging a healthy and competitive economic environment. When speaking about the work being done in Kendall Square specifically, Ms. Westwater at KSA emphasized the importance of developing strong partnerships between businesses and across sectors (Westwater 2020). Because transportation systems extend beyond community boundaries, cooperation and consistency among stakeholders are necessary to accomplish shared goals when working with limited resources. Coordination among communities within the regional transportation network allows for collaborative thinking and strategic resource allocation, which can yield better outcomes than if communities were working independently.

The relatively large number of communities serviced by the public transportation network in the Greater Boston region is a major strength of the system but can also present a coordination challenge. When discussing the strengths of partnerships across sectors and stakeholders, Ms. Brooks cites the high levels of engagement and the interdisciplinary nature of the different committees working within the transportation sector (Brooks 2020). More specifically, Ms. Groll referenced the work and leadership of

MAPC as an example of successful collaboration (Groll 2020). Because MAPC can dedicate staff to priority areas, such as transportation, they can manage important projects that individual cities may not have the time, staff, or resources to accomplish individually. In taking responsibility for leading these inter-community projects, MAPC organizes the many stakeholders, provides space for cities and towns in the region to contribute their input, and ensures that progress is being made through regular monitoring and evaluation. The partnerships formed between MAPC and the participating communities are especially effective because individual city departments are often focused on maintaining city-specific functions, while the MAPC can approach longer-range planning at the regional scale. Travis Pollack, the Senior Transportation Planner at MAPC attributes the agency's effective leadership and ability to coordinate throughout the region to a well-rounded, analytical staff (Pollack 2020). As the public agency responsible for regional collaboration, the transportation department within MAPC is closely involved in coordinating comprehensive and complementary sustainable mobility options for those living and working in the area. Staff in different areas of planning, such as housing and land use, are all able to work together which provides strength and well-rounded expertise.

In addition to the work being done by the public sector, private sector businesses and employers also have a role in contributing to the region's transportation environment. TransAction helps their clients create transit programs and plans that comply with municipal guidelines, such as Cambridge's Parking and Transportation Demand Management Ordinance (1998). Although TransAction is largely dependent on considering the existing system and regulations, the company must also stay informed of continually evolving transportation innovations and legislative efforts.

Because transportation technology and trends are constantly evolving, there are numerous innovative ways companies and municipalities are engaging in this conversation and working to reduce SOV commuting. One creative way that companies are attempting to lower employee SOV rates, while addressing the service limitations associated with the public transit system, is by securing offsite parking locations and providing company shuttles (Brooks 2020). According to Ms. Brooks, this approach has been an opportunity for companies to work with businesses and utilize existing parking spaces that are more typically used during off-peak hours, such as hotels and churches.

Transportation Network Companies (TNCs), such as Uber and Lyft, provide another transportation option with the potential to solve the first and last mile challenge within the TDM environment. Despite the creative ways vehicle sharing and its associated technology can be employed, there are conflicting results regarding the effectiveness of TNCs in replacing car trips (Brooks 2020; Pollack 2020). Although TNCs represent a relatively new area of research, the nuanced relationship between TNCs and public transit use is a topic of interest for many who are engaged within the urban transportation realm (Nelson and Sadowsky 2018). There is evidence for a complementary relationship with TNCs supplementing existing public transit use and a positive association between these modes (Hall, Palsson, and Price 2018; Sikder 2019). However, there is also evidence showing that ride-hailing services more often replace active or public transportation trips (Lavieri and Bhat 2019). Other research indicates a more nuanced relationship between the introduction of TNC services and the different public transit modes impacted (Babar and Burtch 2019). In addition to effects on public transit use, the entry of TNCs into the transportation system is negatively associated with vehicle ownership (Sabouri, Brewer, and Ewing 2020) and registration (Ward et al. 2019), and has the potential to reduce parking demand (Henao and Marshall 2018). Despite the potential land use benefits gained from the introduction of TNCs, there is conflicting evidence that these services add to (Qian et al. 2020; Erhardt et al. 2019) or reduce (Ward et al. 2019) traffic congestion and pollution. Overall, many of these trends are dependent on the environment in which they are operating and the demographic characteristics of users (Nelson and Sadowsky 2018; Dias et al. 2017).

Lastly, the interviewed individuals at MAPC, TransAction, and CDD indicated that the growing micro-transit trend could provide an additional resource that may help to fill in service gaps and offer small-scale mobility options (Brooks 2020; Groll 2020; Pollack 2020). According to the National Association of City Transportation Officials (NACTO), shared micro-mobility trips, or those using shared bicycle and e-scooter systems, increased by more than double between 2017 (35 million) and 2018 (84 million) (“Shared Micromobility in the U.S.: 2018” 2019). In this report, station-based bike-shares are most frequently used as connections to transit. As micro-mobility options continue to expand, this represents a promising trend with the potential to introduce more multimodal trips.

While shuttles, TNCs, and micro-mobility options currently provide a way to supplement the transportation system, research and coordination among all stakeholders are still required to make these options a more fully integrated component of the larger transportation network.

6.2.3.2 Community Values

In addition to coordinated, comprehensive policies, societal support and political will are crucial components when advocating for large-scale change (Batty, Palacin, and González-Gil 2015). Because a transition to a more sustainable transportation system requires behavioral shifts and large investments, public officials and community members must be willing to advocate for and support these changes.

Therefore, ensuring the successful implementation of policies and programs requires aligning policy actions with the broader, long-range vision of the community. Ms. Groll emphasized the significance of implementing policies that support these goals (Groll 2020). Policies have the power to guide actions, influence funding decisions, and hold responsible groups accountable. Because they reflect the priorities and values of the community, they help to encourage and enable the type of development that residents are most interested in achieving.

In Cambridge, progressive policies, such as the Vehicle Trip Reduction Ordinance (1992) and the Parking and Transportation Demand Management Ordinance (1998), have helped to advance the City's goal of reducing car usage by supporting the development of a walkable, bikeable community. These two policies contribute to Cambridge's vibrant, sustainable quality of life by establishing guidelines that shift the transportation conversation away from accommodating personal vehicles and toward encouraging alternative modes. Ms. Brooks credits Cambridge's strong result-oriented policies for these successes, further confirming Ms. Groll's emphasis on thoughtful policy. In contrast to neighboring towns and cities which implement policies that are goal-oriented and largely based on good faith, Cambridge's PTDM policies and requirements rely on measurements and quantifiable results (Brooks 2020). In establishing policies that prioritize pedestrian and bike-friendly infrastructure, the City signals their dedication to reducing residents' need to own personal vehicles. Although this paradigm shift required time and investment, Cambridge is now recognized as a community that rates among the highest walk, transit, and bike scores in the country ("Living in Cambridge" 2020). In addition, according to the American

Community Survey, the drive alone rate for Cambridge residents (26.6%) is close to half that of Massachusetts (70.2%) and of the United States as a whole (76.4%) (U.S. Census Bureau 2018e).

Because policies reflect community values and priorities, they have an important role in guiding decision-making processes. One of the most important aspects of the decision-making process is the appropriate allocation of resources. When attempting to lower the rates of car use and GHG emissions in London, Metz (2015) suggested that the City's successful reductions can be attributed to strategic investment decisions. By implementing policies and thoughtful interventions that prioritize rail transport instead of the more traditional strategy of increasing road capacity for personal vehicles, London has been able to accommodate increases in population density with minor increases in car traffic (Metz 2015). Because Cambridge residents value the use of alternative transportation modes and City policies reinforce this vision, the allocation of funds toward projects that support these goals is widely supported by the general public. Societal support and political will are both necessary in the decision-making process, but employers can also further community goals by working with local governments to support healthy, vibrant neighborhoods.

6.3 Other Considerations and Challenges

Numerous other factors and considerations must be acknowledged when trying to implement programs and policies that shift commuting behavior toward more sustainable modes. Two important challenges that have a direct impact on transportation and commuting patterns, but are not fully addressed in this thesis, are the broader influences of land use and human behavior.

6.3.1 Land Use and Residential Patterns

The ways humans interact with the physical environment and choose to move around space are highly interdependent. In addition, land use patterns and the development of transportation systems are heavily influenced by a wide range of factors including government priorities and policies, available technologies, and constantly evolving social constructs. Denser, more mixed-use development, often seen in urban areas, is associated with reduced vehicle miles traveled and reduced car ownership, while sprawling development, often seen in suburban and rural areas, is associated with the inverse (Kuzmyak

2012; Litman 2020a; Schiller, Kenworthy, and Kenworthy 2010). Although the focus of this study is Kendall Square - a highly dense, urban neighborhood in the Greater Boston area - employees at these companies are commuting from diverse communities throughout the region and the surrounding states.

When asked to provide reasons for driving alone and offering changes that may inspire personal shifts from SOV commuting to alternative modes, survey respondents frequently mentioned housing and work locations. The first and last mile challenge is especially relevant for many individuals who are not within a reasonable distance to public transit options. In communities where there is limited access to transit, personal automobiles often fill this gap in service. As a result, addressing the spatial mismatch between residential areas and jobs and shifting away from driving will require forward-thinking housing and land use planning (Dill and Wardell 2007). Current planning concepts, such as smart growth and TOD, are popular approaches for guiding and prioritizing development, as mentioned by employees at MAPC, KSA, and MBTA. To fully realize the goals of these planning concepts, current land use policies must be reassessed to support behavioral and development shifts in the long-term (Maibach, Steg, and Anable 2009).

Throughout the past century, there have been numerous demographic transitions between rural and urban areas. These often coincide with the development of jobs and amenities, economic health, and generational preferences. Millennials currently represent the country's largest generation and a relatively large percentage of the workforce. Studying the residential and occupational preferences of this generation receives a lot of attention because of the large impacts that millennials' consumption choices and behavior have on the country's economic, political, and social landscape. While some conclude that millennials tend to prefer living in urban centers (Y. Lee, Lee, and Shubho 2019; H. Lee 2020), some argue that they still exhibit similar desires for the suburbs as previous generations (Kotkin 2016; Fagan 2018). Others conclude that the trends are not easily summarized in a positive or negative trend (Capps 2018). Although there are conflicting conclusions about millennials' preferences for city living, many companies have adapted to try to attract and retain millennial employees by relocating offices to urban areas (Fisher 2015; Weber 2013).

6.3.2 Habit and Human Behavior

Based on survey responses, the two of the largest barriers to encouraging employees to shift commuting modes away from SOV travel are family responsibilities and personal commitments. When asked about potential incentives to encourage a mode shift, many participants indicated that there would be nothing that could convince them to change their commuting behavior. An inability to shift personal responsibilities and an unwillingness to change current habits present significant challenges when trying to implement policies and programs that reduce SOV commuting rates.

The United States is heavily dependent on personal vehicles, with the highest VMT rates (per capita) among similarly developed nations (“Vehicle Travel by Selected Country (Metric)” 2010). The United States’ workforce’s tendency to travel by personal vehicle presents a challenge when trying to introduce a large-scale shift to more sustainable modes. When the default is to travel by car, and habits are already established, it can be difficult to encourage individuals to reconsider their behavior (Kristal and Whillans 2019).

Another consideration related to human behavior is the importance of access to, knowledge of, and familiarity with the alternatives being promoted. As Cass and Faulconbridge (2016) explain, mode shifts rely on several factors, some of which depend on personal competencies. Being uncomfortable or unsure of how to bike or read transit schedules act as barriers to the adoption of these commuting modes (Cass and Faulconbridge 2016). Instead of deciding to learn how to use an alternative mode, people tend to continue using the modes that they are most familiar with, which is often commuting by personal vehicle. This could be an area where employers’ marketing campaigns and educational materials help to bridge the gap.

6.4 Limitations

There are many factors affecting mode choice and commuter behavior. Although the findings from this thesis contribute to the growing area of research on the impact of employer-provided benefits, it is important to acknowledge the limitations of this study, which have an impact on the generalizability and transferability of the results.

In addition to the limitations and assumptions mentioned previously in the methods section, there are also more general limitations that apply to the study as a whole.

6.4.1 Geography and Culture

The geographic focus of this study is Kendall Square in Cambridge, MA, a progressive city within the Greater Boston metropolitan region. Therefore the results only represent a small subset of the commuters within the Greater Boston region. The social, geographical, economical, and political characteristics specific to Cambridge and the Kendall Square neighborhood enable companies and the city to adopt programs and policies that may not be viable or applicable in other regions of the country. Some of the characteristics of this area include a high concentration of innovative companies, close proximity and access to an extensive public transportation network, and a highly educated population and workforce. In addition to high educational attainment and Cambridge's prominent role in the knowledge economy, the progressive political atmosphere of the city and the surrounding region strongly influence the prioritization of sustainability and livability. As Ms. Groll explained, Cambridge is lucky to be rich in human, social, and financial capital, all of which help to give the City an advantage when promoting sustainable commuting initiatives and attracting companies who are supportive of this vision (Groll 2020).

6.4.2 Scope

The data gathered and analyzed in this research is only representative of one week. Because employees reported on their commute modes during the survey week, the responses may not reflect their general commuting patterns. Variation or irregularities in personal schedule may have influenced some of the responses. One way this limitation is addressed in previous surveys is by asking participants to provide their primary and secondary modes (Schneider 2013; Heinen and Chatterjee 2015). However, while this alternative method may simplify the survey responses and eliminate possible anomalies, it also has the disadvantage of obscuring more nuanced commuter behavior.

6.4.3 Observational Results

Because this thesis relies on commuter-reported survey data, the findings are observational. Observational research techniques can illustrate correlations and trends; however, participants are still functioning within the natural world and their behavior is still impacted by outside influences. As a result, the observed effects may be due to factors that are beyond the main variables of interest - employer

incentives and employee commuting modes. Without the use of control groups, which are often present in experimental research, results of observational research are not as conclusive as the cause-and-effect results that can be derived when conditions are more tightly monitored.

6.4.4 Theoretical Expectations

The survey asked participants if they would be willing to switch commuting modes if provided with a range of commuter improvements and incentives. While it is valuable to prompt people to think about the factors that would encourage a mode shift, it may lead to inflated expectations. While responding, the survey participants may have believed that they would change if they were provided with additional resources, like a free bike-share membership or access to showers and locker rooms; however, habits are difficult to break and intent in an ideal or theoretical situation is different than making behavioral changes in reality. Therefore, it is important to consider that implementing and constructing the types of improvements provided in the survey options may appear promising, but may not achieve the degree of change indicated by the survey responses. Seeing these larger-scale results would likely require several coordinated measures and would necessitate longer-term observation.

6.5 Future Research

Based on the limitations listed above, there are numerous ways to expand upon and supplement the research conducted as part of this thesis. Some directions for future research include reconsidering the temporal and spatial scale, employer and employee profile, and study design.

6.5.1 Temporal Scale

Because of Cambridge's progressive transportation-related policies, TransAction has been conducting surveys similar to the one used in this research, over the past two decades. While companies, employees, and incentive programs change over time, looking at employee mode split and employer-provided incentives over a range of years would be beneficial in revealing trends in commuting patterns. Using data from a longer time period would also allow commuter behavior to be studied in conjunction

with policy and infrastructural changes. The longer time frame could deepen our understanding of the influence that more abstract social and cultural shifts have on behavior.

An additional research direction could be to investigate the impact of weather conditions and seasonal variation on commuting behavior. TransAction worked with their clients to distribute these surveys during warmer weather months and in an area of the country that experiences four distinct seasons. Further research could investigate the commuting behavior of employees at these same companies during colder months or could be conducted in other regions of the country that have a more temperate climate.

6.5.2 Spatial Scale

Because this study looks at employees from a small number of companies within one wealthy, urban neighborhood in Greater Boston, additional research could incorporate larger, more diverse geographic regions. Exploration of commuting trends in regions beyond Massachusetts and New England would be beneficial in understanding whether incentive programs yield varying results in other parts of the country. Similarly, research that examines the commuter behavior of employees working in more rural, suburban, or lower-income environments would provide a more comprehensive understanding of the effect employer-provided incentives have on commuter decisions in places with fewer social and infrastructural resources than Cambridge, MA.

6.5.3 Employer and Employee Profile

While Kendall Square has a high proportion of businesses involved in the technology and research sectors, this does not reflect a majority of the United States. A future sampling of employers in a variety of economic sectors could illustrate the ways the results of this study are more or less applicable to a broader range of companies and individuals. For example, employee profiles of individuals working within the industrial or retail sectors may differ from those in this study in terms of socioeconomic status and access to transportation and housing options, all of which influence the availability of commuting choices.

6.5.4 Study Design

Lastly, the results of this study are largely based on correlational observations. To determine more direct relationships between different variables and commuter behavior, future research could utilize an experimental research design. While this method requires a more systematic approach to designing the study's controls and variables of interest, it would provide researchers with higher levels of certainty when establishing relationships between incentives and commuter behavior.

CHAPTER 7

CONCLUSION

Awareness of climate change has been steadily growing over the past few decades, and with it, increasing concern over the consequences of continuing to operate within a business-as-usual framework. Because the transportation sector represents one of the largest contributors to anthropogenic GHG emissions, the field of sustainable transportation research is gaining attention within the broader fields of civil engineering, economics, sociology, psychology, public health, public policy, regional planning, and geography, among many others.

The transportation system represents a complex network of mobility options that are heavily influenced by the economic, political, and social environment. Approaching and trying to solve issues within the existing system requires collaboration and creative alternatives that rely on technological and infrastructural improvements, policy changes, and cultural behavioral shifts. Improving urban transportation systems and encouraging a more sustainable mode shift has the potential to significantly reduce GHG emissions, achieve municipal and regional sustainability goals, and benefit community members' physical health and quality of life. This thesis focuses on determining ways that employer-provided benefits influence commuter mode choice. These findings can further inform employers, municipalities, and coordinating agencies interested in reducing SOV commuting trips and promoting the use of more sustainable, alternative modes of transportation.

Based on this research, one of the most important factors in initiating a mode shift toward more sustainable transportation commuting among employees is employer investment and buy-in. When companies take an active role in encouraging employees to rethink their commuting habits, by allocating the necessary resources to providing a supportive program of mutually supportive benefits, they are more likely to reduce the rates of SOV use.

In terms of providing incentives, this research illustrates that the provision of free parking significantly increases employee SOV commuting rates, regardless of the provision of corresponding public transit subsidies. The use of personal vehicles is already heavily subsidized as a result of the public policy environment and the way transportation projects are funded. Therefore, the relatively low price of driving does not match the high economic, social, and environmental costs of the high national SOV commuting

rates. To counteract these externalities, more flexible benefits programs should prioritize public transit over driving alone. This can be accomplished by instituting daily parking rates and making public transit and active modes of commuting more convenient and less expensive, or preferably free. In addition to direct transportation subsidies, the implementation of effective informational campaigns is a complementary measure that has the potential to increase employee awareness of alternatives and thus result in more sustainable mode splits.

A third, more general conclusion from this research is that this field of work requires a systems-level approach that incorporates collaboration among all stakeholders. Although the large number of agencies and organizations involved in this type of work all have unique, sometimes competing missions, it is important to prioritize the larger goal of improving transportation sustainability. Diverse perspectives help to drive innovative ideas and solutions; therefore, the establishment of strong partnerships between these different groups will be key to further problem-solving.

In conclusion, the main findings presented in this thesis support previous studies and contribute to the ongoing conversation regarding more sustainable transportation behavior. Although numerous factors influence employee commute choices, these results provide a clearer understanding of employee commuting behavior in response to employer-provided benefits. When attempting to implement widespread shifts in transportation patterns, a coordinated multi-sectoral approach that considers and accommodates the varying needs of employees provides the most promising approach for achieving sustainability goals.

APPENDIX A
SPATIAL DATA SOURCES

| Sources | Original Data | Layer Names | Data Description | Updated |
|---------------------------|----------------------------------|--|---|----------------|
| MassGIS | <i>MBTA Rapid Transit</i> | MBTA_Rapid_Transit.lyr | “station stops on the five subway, streetcar/trolley and Silver Line bus lines in the Massachusetts Bay Transportation Authority’s rapid transit rail network” | Jan. 2020 |
| | <i>Trains</i> | Commuter_Rail_Lines_and_Stops_Active.lyr | “active passenger, freight, and MBTA Commuter Rail and Rapid Transit railways, along with abandoned rail lines and railroad beds now used as rail trails” | April 2015 |
| | <i>MBTA Bus Routes and Stops</i> | MBTA_Bus_Routes_and_Stops_SHP.lyr | “bus routes and stops within the Massachusetts Bay Transportation Authority (MBTA) public transit system” | June 2017 |
| U.S. Census Bureau | <i>Zip Code Tabulation Areas</i> | tl_2019_us_zcta510 | “The 2010 Census 5-Digit ZIP Code Tabulation Area (ZCTA5) National contains attributes for all ZIP Code Tabulation Areas (ZCTAs). These are approximate area representations of U.S. Postal Service (USPS) ZIP Code service areas that the Census Bureau creates to present statistical data for each decennial census.” | 2019 |
| | <i>States (and Equivalent)</i> | tl_2019_us_state | “The Current State and Equivalent National contains attributes for the primary governmental divisions of the United States. In addition to the fifty States, the Census Bureau treats the District of Columbia, Puerto Rico, and each of the Island Areas (American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, and the U.S. Virgin Islands) as the statistical equivalents of States for the purpose of data presentation.” | 2019 |

APPENDIX B EMPLOYEE SURVEY

SAMPLE - 2018 Employee Commuter Survey

Businesses located in Cambridge are required by the City of Cambridge to conduct a survey of employees to find out how they commute to work. Please fill in an answer to EACH of the following questions and submit the responses. To show our appreciation we are holding a prize drawing for an iPad and a Kindle. Thank you for participating in this survey.

• Where do you live?

City _____
State _____
Zip Code _____

• What time do you usually begin work in the morning?

- Before 6:00AM
 6:00-6:59AM
 7:00-7:59AM
 8:00-8:59AM
 9:00-9:59AM
 After 10:00AM

• What time do you usually end work in the evening?

- Before 4:00PM
 4:00-4:59PM
 5:00-5:59PM
 6:00-6:59PM
 7:00-7:59PM
 After 8:00PM

• How often do you vary your work hours by more than 30 minutes from these times?

- Never
 1-2 days/week
 3+ days/week
 1-2 days/month

• How many hours do you usually work each day?

- Less than 2
 2 to 5
 6 to 8
 More than 8

• How long does it take you to travel to work on a typical day? (minutes one-way)

- 0 to 15 min
 16 to 30 min
 31 to 45 min
 46 to 90 min
 More than 90

• How many miles (one way, approximately) do you travel from home to work on a typical day?

- 0 to 10 miles
 11 to 20 miles
 21 to 40 miles
 41 to 60 miles
 61+

SAMPLE - 2018 Employee Commuter Survey

Please indicate how you commuted to work each day during the survey week of May 14-18, 2018.
(please note primary mode only)

Monday

- Walk the entire way
- Rode personal bicycle the entire way
- Rode Hubway bikeshare the entire way
- Drove alone the entire way
- Drove and rode bicycle (park & pedal)
- Public transportation + walked
- Public transportation + personal bicycle
- Public transportation + Hubway bikeshare
- Public transportation + drove/carpooled/shuttle
- Carpool (2- to 7-person)
- Vanpool (eight- or more-person)
- Took taxi/Uber/Lyft WITH other passengers
- Took taxi/Uber/Lyft by yourself
- Was dropped off at work
- Worked at home
- I don't usually work this day
- Sick, vacation, business trip, personal time or jury duty
- Other (scooter, skateboard, etc.)

Tuesday

Please select one ...

Wednesday

Please select one ...

Thursday

Please select one ...

Friday

Please select one ...

SAMPLE - 2018 Employee Commuter Survey

- If you drive to work, where is the vehicle usually parked?

- 350 Kendall Garage
- 650 East Kendall Garage
- Other parking structure/lot
- On-street

- If you drive only part of the way, where do you usually park?

- Train/Transit Station
- Park-and-Ride Lot
- Parking lot/structure off-site
- On-street

- How many times a month (on average) do you use your OWN car for WORK-RELATED BUSINESS during the day?

- None
- 1 to 4
- 5 or more

SAMPLE - 2018 Employee Commuter Survey

Please answer the following questions if you drive alone to work. If you do not drive alone, please click on "I do not drive alone to work".

What are your reasons for driving alone?
(mark all that apply)

- I do not drive alone to work
- Most convenient way to commute
- Cheapest way to commute
- Fastest way to commute
- Safest way to commute
- Enjoy my privacy, prefer driving alone
- Free/cheap parking at work
- Physically disabled
- Need car for work-related trips
- Need a car for errands before/after work
- Need car in case of emergencies
- Difficulty finding others with whom to carpool
- Take children to school or daycare
- Work hours are irregular
- Transit schedules or routes don't work for me
- Concern about bad weather
- I have a lot of things to carry with me
- Other (please specify) _____

SAMPLE - 2018 Employee Commuter Survey

Does your company or building owner provide any of the following INCENTIVES OR SERVICES?

| | Yes | No | Not sure |
|--|-----------------------|-----------------------|-----------------------|
| Emergency Ride Home program in case of emergencies | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| On-site information on transit routes and schedules | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Shuttle to a train/bus station | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Subsidy for transit/vanpool fares | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Preferential or reserved parking for employees who rideshare | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Help finding someone with whom to carpool/vanpool | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Vans available for ridesharing | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Bicycle storage | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Financial incentives for biking and walking | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

How likely would you be to change to ridesharing, transit or other commuting alternatives IF THE FOLLOWING INCENTIVES OR SERVICES were available? (mark one space for each option)

| | Very Likely | Somewhat Likely | Not Likely |
|--|-----------------------|-----------------------|-----------------------|
| Emergency Ride Home program in case of emergencies or unscheduled overtime | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Hubway station near my work/home | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Free Hubway membership | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| On-site information on transit routes and schedules | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Shuttle to a train/bus station | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Subsidy for transit fares | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Subsidy for vanpool fares | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Preferential or reserved parking for employees who rideshare | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Help finding someone with whom to carpool/vanpool | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Vans available for ridesharing | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Car made available for business use during the day | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Easier more bicycle storage made available | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Showers and lockers made available | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Financial incentives for biking and walking | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| On-site parking fees raised by 10% or more | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other (please specify) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

What would cause you to switch from driving alone to another mode of transportation?

- If you took public transportation for all or part of your commute, which route(s) did you use? (check all that apply)
If you do not use public transportation, please click "I do not use public transit" below.

I do not use public transit

MBTA Red Line

MBTA Green Line

MBTA Orange Line

MBTA Blue Line

MBTA Silver Line

Commuter Rail to North Station

Commuter Rail to South Station

Commuter Rail to Porter Square

MBTA Bus Route

EZRide

Shuttle bus

If you selected bus route, please specify route number(s) _____

SAMPLE - 2018 Employee Commuter Survey

· Please rate the following MBTA and EZRide services on a scale of 1-poor to 5-good.

| | Reliability | Frequency | Hours of Operation |
|----------------|----------------------|----------------------|----------------------|
| MBTA Bus | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| MBTA Subway | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| Commuter Rail | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| EZRide Shuttle | <input type="text"/> | <input type="text"/> | <input type="text"/> |

· Please provide us with any additional comments about the MBTA and EZRide services.

· If you walk/bike/take transit/carpool, why? (check all that apply)

- Most convenient way to commute
- Cheapest way to commute
- Fastest way to commute
- Safest way to commute
- Most fun way to commute
- Better for the environment
- Too much traffic on streets and highways
- Parking is expensive at work
- Do not own a car
- Take kids to school or daycare or after school activities
- Work hours are irregular
- Transit schedules or routes do not work for me
- For exercise
- Other (please specify) _____

Interested in finding someone with whom to carpool? You are eligible to use a Ridematching Program that helps form carpools. How does it work? Simply go to:

<http://www.ecommuter.org>

and follow the simple instructions to see if you have any matches. Try it, it's free.

Just click on the submit button and you are all set!

Thank you for completing this survey.

**APPENDIX C
EMPLOYER SURVEY**

PTDM Tenant Questions

_____, as required by the City of Cambridge, must complete an evaluation of the effectiveness of its Parking and Transportation Demand Management (PTDM) plan. As part of this evaluation, tenant employees must be surveyed to determine how they commute to work. The survey week will be April 23-27, 2018. In preparation for completing this report, we need the following information:

Company Name: _____

Company Address: _____

Contact Person's Name: _____

Contact Person's Telephone#: _____

Contact Person's Email Address: _____

Total Number of Employees at this Address: _____

Number of Cambridge residence employees hired since June 30, 2017 _____

Does your company provide any of the following incentives?

Sale of MBTA Transit Passes? _____

If yes, how many are sold per month: _____

Are the transit passes sold through payroll deduction? _____

Subsidize MBTA Transit Passes? _____

If yes, what is the amount of the subsidy? _____ % or \$ _____

Do you post MBTA and/or EZRide schedules in central locations? _____

Do you charge your employees for parking? _____ What is the rate? _____ mth/yr

Please list any other incentives that your company provides to help promote the use of transit, carpooling, biking and walking:

Thank you for your cooperation.

APPENDIX D RESULTS

The three benefits corresponding between the employee (left) and employer (right) surveys.

| | |
|--|---|
| <p>Emergency Ride Home program in case of emergencies</p> <p style="border: 1px solid orange; padding: 2px;">On-site information on transit routes and schedules</p> <p>Shuttle to a train/bus station</p> <p style="border: 1px solid orange; padding: 2px;">Subsidy for transit/vanpool fares</p> <p style="border: 1px solid orange; padding: 2px;">Preferential or reserved parking for employees who rideshare</p> <p>Help finding someone with whom to carpool/vanpool</p> <p>Vans available for ridesharing</p> <p>Bicycle storage</p> <p>Financial incentives for biking and walking</p> | <p>Does your company provide any of the following incentives?</p> <p>Sale of MBTA Transit Passes? _____</p> <p>If yes, how many are sold per month: _____</p> <p>Are the transit passes sold through payroll deduction? _____</p> <p style="border: 1px solid orange; padding: 2px;">Subsidize MBTA Transit Passes? _____</p> <p>If yes, what is the amount of the subsidy? _____ % or \$ _____</p> <p style="border: 1px solid orange; padding: 2px;">Do you post MBTA and/or EZride schedules in central locations? _____</p> <p>Do you charge your employees for parking? _____ What is the rate? _____ mth/yr</p> <p style="border: 1px solid orange; padding: 2px;">Please list any other incentives that your company provides to help promote the use of transit carpooling, biking and walking:</p> <p>_____</p> <p>_____</p> |
|--|---|

The full, ranked list of survey-provided reasons for choosing to commute by SOV.

| Check all that apply... | Total Respondents | Response Rate (%) | Rank |
|---|-------------------|-------------------|------|
| <i>I do not drive alone to work</i> | 1059 | 44.8% | 1 |
| <i>Take children to school, daycare or activities</i> | 760 | 32.1% | 2 |
| <i>Most convenient way to commute</i> | 641 | 27.1% | 3 |
| <i>Errands before/after work</i> | 599 | 25.3% | 4 |
| <i>Fastest way to commute</i> | 515 | 21.8% | 5 |
| <i>In case of emergencies</i> | 340 | 14.4% | 6 |
| <i>Work hours are irregular</i> | 287 | 12.1% | 7 |
| <i>Transit schedules or routes don't work for me</i> | 273 | 11.5% | 8 |
| <i>Enjoy my privacy, prefer driving alone</i> | 256 | 10.8% | 9 |
| <i>Free/cheap parking at work</i> | 131 | 5.5% | 10 |
| <i>Difficulty finding others with whom to carpool</i> | 130 | 5.5% | 11 |
| <i>Cheapest way to commute</i> | 119 | 5.0% | 12 |
| <i>Concern about bad weather</i> | 101 | 4.3% | 13 |
| <i>I have a lot of things to carry with me</i> | 98 | 4.1% | 14 |
| <i>Safest way to commute</i> | 84 | 3.6% | 15 |
| <i>Need car for work-related trips</i> | 48 | 2.0% | 16 |
| <i>Physical disability</i> | 10 | 0.4% | 17 |

The process for categorizing open-ended survey responses providing reasons for choosing to commute by SOV.

| Broader Themes | Themes | # of Mentions* | Codes | # of Mentions* |
|----------------------------|---------------------------------------|----------------|--|----------------|
| Personal | Family, Individual Scale | 26 | Pre/post-work activities | 10 |
| | | | Family responsibilities | 6 |
| | | | Personal disability/injury | 3 |
| | | | Preference | 3 |
| | Employer or Policy, Larger Scale | 13 | Work schedule/responsibilities | 9 |
| | | | Familiarity/awareness/knowledge | 4 |
| Transit limitations | Service, Reliability | 16 | Unreliable, delays, unpredictable | 16 |
| | | | Comfort (crowded, old, dirty, unhealthy) | 2 |
| | Inadequate infrastructure | 8 | No parking at stations | 3 |
| | | | Overcapacity of transit infrastructure | 3 |
| | | | No accessible transit | 2 |
| | Efficiency | 7 | Time, efficiency, transfers | 6 |
| | | | Cost | 3 |
| Irregularity | Irregular occurrence | 10 | Schedule and commitments | 6 |
| | | | Weather | 2 |
| | Do not drive | 6 | No car | 1 |
| Other | Miscellaneous | 6 | | |
| | Motorcycle | 4 | | |
| | Coordinate ride with partner part-way | 3 | | |

*When coding the open-ended survey responses for this question, I used # of mentions instead of # of participants or # of survey responses because some participants mentioned multiple reasons for choosing to commute by SOV within their one open-ended response. The number of mentions does not always equal the larger, more general category because some participants did not provide responses that could be easily categorized. The more refined "Codes" are used to show the prevalence of common responses or responses that are important to note.

The full, ranked list of survey-provided reasons for choosing to commute by alternative modes.

| Check all that apply... | Total Respondents | Response Rate (%) | Rank |
|--|-------------------|-------------------|------|
| Most convenient way to commute | 785 | 33.2% | 1 |
| Cheapest way to commute | 611 | 25.8% | 2 |
| Fastest way to commute | 501 | 21.2% | 3 |
| Better for the environment | 417 | 17.6% | 4 |
| Too much traffic on streets and highways | 341 | 14.4% | 5 |
| Parking is expensive at work | 336 | 14.2% | 6 |
| For exercise | 314 | 13.3% | 7 |
| Do not own a car | 284 | 12.0% | 8 |
| Most fun way to commute | 226 | 9.6% | 9 |
| Safest way to commute | 120 | 5.1% | 10 |
| Work hours are irregular | 98 | 4.1% | 11 |
| Transit schedules or routes do not work for me | 62 | 2.6% | 12 |
| Take kids to school or daycare or activities | 40 | 1.7% | 13 |
| Easy to find others to carpool with | 5 | 0.2% | 14 |

The process for categorizing open-ended survey responses providing reasons for choosing to commute by alternative modes.

| Themes | # of Mentions | Codes | # of Mentions |
|--|---------------|--|---------------|
| Personal | 25 | Use time for other activities/work | 8 |
| | | Coordination with spouse/friend/relative | 6 |
| | | Driving is stressful/difficult | 3 |
| | | Flexibility | 2 |
| | | Health/exercise | 2 |
| | | Infrequent or unable to drive | 2 |
| | | Sustainability/car-free goals | 1 |
| | | Work from home | 1 |
| External | 5 | No parking available | 2 |
| | | Vehicle unavailability | 2 |
| | | Bike incentives available | 1 |
| Comparing within alternative modes* | 11 | | |
| Other | 2 | | |

* When respondents responded to this question, some provided reasons indicating that they decided between different alternative modes. For example, one individual who chose "Walk the entire way" three of the five days responded: "A 4 mile walk/one way is much faster than taking the T Red Line." Another individual who chose "Rode Hubway bikeshare the entire way" three of the five days responded: "MBTA Red Line breaks down frequently."

The process for categorizing participants' open-ended suggestions by responsible parties.

| Broader Themes | # of mentions | Codes | # of mentions | Responsibility |
|---|----------------------|--|----------------------|----------------------------|
| Improved Public Transportation | 160 | Reliable/frequent | 54 | Government |
| | | More direct routes | 22 | Government |
| | | Time efficiency | 22 | Government |
| | | More extensive routes/accessibility/location of stations | 22 | Government |
| | | (Availability/paid) parking at train station | 17 | Government |
| | | Less expensive | 9 | Government |
| | | Flexibility/convenience | 7 | Government |
| | | Personal comfort | 4 | Government |
| | | Infrastructure | 3 | Government |
| Better/safer bike infrastructure | 18 | bike lanes/paths | 8 | Government |
| | | general improvements | 6 | Private-public partnership |
| | | bike share stations | 2 | Company or Developer |
| | | bike parking/secure storage | 2 | Government |
| Employer-controlled | 10 | flexible benefits | 7 | Company or Developer |
| | | telecommuting option | 3 | Company or Developer |
| Personal | 70 | housing/work location | 35 | Personal |
| | | change in personal commitments | 34 | Personal |
| | | owning an electric bike | 1 | Personal |
| External Services | 61 | rideshare/commuter match up program | 37 | Private-public partnership |
| | | (more frequent) work shuttle | 12 | Company or Developer |
| | | (better) park and ride options | 4 | Government |
| | | locker room/shower facilities | 4 | Company or Developer |
| | | emergency ride home | 2 | Company or Developer |
| | | better infrastructure - EV | 2 | Private-public partnership |
| Abstract/external factors | 35 | saving time/money | 22 | External or Abstract |
| | | increased driving costs - money/time | 8 | External or Abstract |
| | | future technologies | 3 | External or Abstract |

| | | | | |
|-----------------------|----|--|----|----------------------|
| | | affordable onsite childcare | 2 | External or Abstract |
| Other | 20 | ambiguous/misinterpretation | 10 | Other |
| | | not sure | 4 | Other |
| | | inconsistent schedule | 4 | Other |
| | | motorcycle | 2 | Other |
| | | family commitments | 21 | Personal |
| Nothing | 76 | (no further explanation) | 20 | Personal |
| | | other | 16 | NA |
| | | physically unable to drive/no car | 10 | Personal |
| | | accessibility/efficiency | 5 | Personal |
| | | comfort/privacy | 4 | Other |
| | | Rarely/do not drive | 48 | NA |
| Not applicable | 70 | "n/a" | 12 | NA |
| | | currently use mix/already take alternative in nice weather | 10 | NA |

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