The Myth of the Single Mode Man:
How the Mobility Pass Better Meets Actual Travel Demand

By

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Bachelor of Arts in Urban Studies
Columbia University, 2006

Submitted to the Department of Urban Studies and Planning and Department of Civil and Environmental Engineering in partial fulfillment of the requirements for the degrees of

Master in City Planning
and
Master of Science in Transportation

at the

Massachusetts Institute of Technology

June 2009

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ABSTRACT

The goal of this thesis is to investigate how employer transportation subsidy programs can result in more sustainable outcomes. Cities are growth machines that increasingly seek to mitigate the effects of that growth caused by commensurate increases in auto usage, including congestion and emissions. Employers have an interest in reducing the costs of providing parking, and reducing local congestion, in part to attract and retain employees. Because of coincidental interests, municipalities and employers are natural allies in the fight to control the spatial effects of auto usage.

Employers are the nexus for breaking the cycle of auto usage. Federal transportation fringe benefits that allow transit passes to be paid through the employer on a pre-tax basis can subsidize increased usage of transit. The initial research focuses on MIT because of its evolving environmental mission, its size, which allows it to internalize externalities, and its students, who will shape policies that affect mode choice both in the US and internationally.

The myth of the single mode man is that people take the same mode to commute to work each day. In practice this myth results in subsidies that encourage more employees to drive than otherwise would. MIT survey data indicates that the single mode man is a good model for significant populations in urban areas: those who are either transit captive, or have a completely car-oriented work or home location. However, a significant portion of the population—30%+ at MIT—is multimodal; they take different modes to work depending on the day. Traditional employer subsidies of transit passes do not serve this group well, because they may not take transit enough to opt in to a transit pass program. Current employer subsidies are a hodgepodge of past decisions, historical accidents, and good intentions. They encourage employees to make choices that are 1) economically inefficient for the individual, 2) cost the employer money, and 3) cause congestion and pollution.

Employers' current tools to regulate demand for parking while attracting and retaining employees seem to have reached diminishing returns. Universal Access passes have shown promising results in reaching the remaining drivers by providing low cost access to zero marginal cost transit. With these passes, employers pay a single price for all of their employees' transit usage for a defined period. Reducing the barriers to mode switch by allowing mode blending (partial mode switch) can result in an "everyone wins" situation for the employer, the municipality, the transit agency, employees, and society as a whole.

This thesis proposes and predicts the effects of one such program at MIT, the Mobility Pass, which provides a single transportation benefit combining parking and a Universal Access pass on a smart card. The proposal is promising as an approach for employers in metropolitan areas with transit systems, and provides insight into multimodal activities for a substantial minority of the public that can help shape the design of programs elsewhere.

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Fred & John. Your counsel, ideas, and disagreements are what made this endeavor worthwhile.

Nigel, Mikel and Chris. Your wise wisdom is what got me here in the first place.

Larry. Thank you for providing what all good little graduate students need.

Maggie & Paul. Apologies for not calling more often.

And to Carrie. I have neither the proper quantity nor quality of words.

PROLOGUE

I believe in cities. I believe that cities work because they improve denizens' choices. What I mean is that I believe that the ability to choose, and by extension the variation in choices based on changing circumstances, is a fundamental advantage. Transportation researchers, policy-makers, and human resources administrators shape the way people make these choices. They make assumptions in the samples their models are based on, their policies, and their benefits packages about how we *do* behave, and how we *should* behave. These assumptions describe *and* affect the way we travel. Many of these assumptions are good, right and true, but one in particular is egregiously wrong. Many people in cities do not travel to work the same way every day. That is a myth. And the belief in this myth—as a simplifying assumption for modelers, and as a basis for government and employer transportation policies and subsidies—leads to inequitable outcomes and misguided policy choices. Decisions made based on this myth remove choices from citizens, and therefore make cities function less efficiently.

In urban areas many people have a choice of modes available for their activities on any given day. This includes their commute to work. These choices are manifest in the stories we tell each other. I walk, no matter the weather, but I sometimes take the bus halfway home, if it is outside the front door of my office. Every once in a while, when I am particularly late, I take a taxi. I know people who drive when they are going to Cape Cod for the weekend, but take public transit other days. And I have heard of people who drive every day. In short, some people choose the same mode each day, no matter their activity pattern; some people vary depending on the activity; some people may even change for the same activity (depending on the weather, the timing, or on a whim). This flexibility is one of the advantages of urban areas – residents can optimize trip patterns in more ways than in non-urban areas. Better understanding of this flexibility make programs that reduce congestion and air pollution via incentives to encourage more sustainable patterns more feasible.

1 Introduction

The goal of this thesis is to investigate the extent to which employer transportation subsidy programs can result in more sustainable outcomes. Cities are growth machines that increasingly seek to mitigate the effects of that growth caused by commensurate increases in auto usage. Auto usage has negative externalities that impact the desirability of those cities; congestion that increases commute times, emissions that reduce the walkability of the area, and greenhouse gases which have increasingly become not only a global, but a local issue. At the same time, employers, also seeking to maximize profits and/or a broader mission, have an interest in reducing the costs of providing parking, and reducing the amount of congestion to their work site. Parking is an expensive benefit to provide. Underground parking costs more than $100,000 per space in capital alone in Cambridge. Full cost recovery from these spaces by raising prices conflicts with a desire to attract and retain employees. Because of coincidental interests, municipalities and employers are natural allies in the fight to control the spatial effects of auto usage. Policies that decrease auto usage are also positive environmentally.

As can be seen in Table 1-1, there are a myriad of other interests across governmental functions and non-governmental actors that have an interest in one or more of these objectives. They are all stakeholders in the outcomes that can be achieved by joint action, and each has a role to play in enabling change that is positive environmentally, even if their primary objective is not to decrease emissions or greenhouse gases.

Table 1-1. Selected Objectives Of Relevant Transportation Actors

	Employee	Employer	City	State & Region	Transit Agency	Federal (fiscal)	Societal
Emissions			✓	✓		✓	✓
Global Warming				✓		✓	✓
Congestion	✓	✓	✓	✓			
Parking Costs and Availability	✓	✓		✓			
Transit Agency Operating Rev.			✓	✓	✓	✓	
City Desirability	✓	✓	✓	✓	✓		

1.1 A Growing Problem: Urban To Suburban

These trends are increasingly evident in urban areas. In Cambridge, employers are strongly encouraged through regulatory measures to provide transit subsidies to their employees to encourage employees to commute to work by means other than the car. As suburban areas become denser, the cost of providing parking moves from relatively inexpensive surface lots to more costly structured parking, which increases the pressure on employers to manage the negative effects of growth, since the costs of that growth, which were formerly external (emissions and congestion) are now also internal.

1.2 Why Focus On The Employer?

The focus on the employer as a means to reduce auto usage is made stronger because federal transportation fringe benefits allow both parking and transit at the job location to be paid through the employer on a pre-tax basis. The effect is a significant federal subsidy (up to 33% of the value of the transit pass for employees, and 7% for employers) for transit passes that are purchased through employers. Employer programs also provide a ready means by which consistency of behavior can be encouraged, via regular payroll deductions for transit passes. As government subsidies for transit operations have been eliminated, transit agencies have less direct means by which they can expand their service on existing routes, and thus reduce the demand for auto usage by at the very least increasing utilization of existing service, or optimally attracting new riders through service improvements. This means that there are fewer immediate actions that can be taken to decrease the negative externalities associated with auto usage. If one role of government is to mitigate the externalities of a free market, then operating under political constraints, the federal transportation fringe benefits are a de facto substitute for operating subsidies, of between 25 and 40%. Focusing on employers thus better allows the government to play one of its roles, without needing to increase taxes or other fees, which may be difficult or impossible to achieve politically.

1.3 Why Focus On A University?

Universities are an important subset of employers to focus on. They have institutional missions that advance environmental causes, such as MIT's commitment to "Walk the Talk" on greenhouse gas reduction and energy consumption. They also have a history of innovative programs. They were the first to adopt Universal Access Passes, which provide zero marginal cost transit for the entire University by spreading the costs across the population. Because of their size, Universities internalize many of the problems, such as congestion, that are normally seen as externalities. They have been at the forefront of efforts to manage auto demand and parking costs by mitigation measures that encourage walking, biking, and transit. In large part this also a result of the student populations they serve. These students provide another impetus to focus on Universities first. Current students will soon choose where they want to live, how many autos they want to own, and where they want to travel. They will also shape policies that affect other's choices both in the United States and internationally. Changing their perception of transit and other more sustainable modes of transport is more possible when surrounded by a community that supports transit. The other option is to makes changes later in life, when they have already developed the same patterns that have led to the congestion, emissions, and climate change problems faced today. Universities are a good place to start innovative programs because they provide valuable insight into the design of more wide scale programs for all employers.

1.4 Employer Motivations

Employers have an additional impetus to act. As the costs of building and leasing parking have risen in urban areas, so too have the total subsidies per parking space. By mitigating these cost increases for their employees, many employers now provide a significant subsidy for those employees who choose to drive to work. This subsidy is often significantly higher in both real dollar and percentage terms than the subsidy for transit passes. Employers may not have enough parking supply to meet demand for 100% of employees. Therefore parking policies tend to be a mix of price signals and formal or informal regulatory measures, such as assigning preferred parking by seniority, by "importance to the Institute," by need, etc. The result is often that those people who make the most money also have the best, or the only available parking. Combined with the high subsidies for this parking, this can create the perception of inequitable outcomes. Transit subsidies in this instance are another measure to mitigate the negative effects of disproportionate parking subsidies.

1.5 Time For Innovation

Employer's current tools to regulate demand for parking while attracting and retaining employees, such as transit pass subsidies, seem to have reached a point of diminishing returns on investment. Those people who can easily convert to transit seem to have done so.   Even a 50% subsidy, combined with the federal transit fringe benefits, would require an employee to travel by transit for 6-8 trips per month on average to be advantageous financially. The market for those employees in high transit mode share areas seems to have reached saturation. Employer programs that require employees to affirmatively choose to participate require active change by employees, rather than passive action. Even at a place like MIT, with relatively good transit access and very generous transit benefits, decreasing auto mode shares for employees below 30% is difficult.

Universal Access passes show promise in breaking through to reach the remaining drivers. With these passes, employers pay a single price for all of their employees' transit usage for a defined period, usually a month or a year. These costs are estimated from average mode share in the employer's area, or via a survey of employees. The employer is responsible for the single fare value of the total group usage. For example, imagine an employer who has 100 employees, and 30% of employees' commute to work takes place using transit valued at $100 per month. For the sake of simplicity, ignore employer subsidies and federal policy on transportation fringes. By simple arithmetic, the employees currently pay the transit agency $3,000 per month. Only those 30 people who pay the transit agency have a pass. With a Universal Access pass, the employer pays the transit agency $3,000 each month, and allows all 100 people to have a pass. Since those other people never use transit, it does not cost the employer any more to give them this pass. The employer redistributes these costs to their employees however they want; with or without additional subsidy, charging all employees equally, or discriminating based on price. If this increases usage of transit by the cohort who did not use it before, then the employer costs go up, but the value employees receive also goes up, and the cost of parking subsidies goes down. However, these programs mostly do not have good data on usage, and thus are based on mode share estimates within an area, or survey data. Without full information it is hard for both employers and transit agencies to judge whether these programs have increased revenue and ridership, although it seems likely that they do.

Pay-per-ride passes, with or without monthly or daily capping are in use in places as disparate as London and Phoenix. They provide a "best value" for the customer based on their day or month's travel patterns. In London they are available widely, using daily capping, while in Phoenix their use has been limited to employer programs and monthly capping. They potentially allow employers to cost-effectively distribute transit passes even to those people who use transit infrequently, because the only cost is for those fares actually used.

1.6 New Tools And Data

Smart cards allow the usage of a discrete group, such as employees, to be tracked on a per-ride basis. With this data, there is no longer a need for the usage estimates of Universal Access Passes. By tracking actual ridership, both employers and transit agencies can ensure that the program is measurable. MIT's unique wealth of data is derived from biennial surveys of employee commute behavior over the course of a week, tracked by employee for three surveys (2004, 2006, and 2008). This data set allows significantly more insight into how people actually behave than has been previously available for a specific employer. Combined, these developments permit the design of better ways to understand and meet current travel demand. This new knowledge allows new thinking about ways of changing behavior that exploit the increase in the cost of providing parking, and result in positive outcomes for all parties.

1.7 The Single Mode Man

The current structure of transit and parking subsidies serve the single mode man well. Single mode man travels via the same mode every day, so monthly transit passes and monthly or annual parking permits meet his needs. He "makes the most" of these incentives. The mythical single mode man is based on the conception of static behavior at a given point and time and the assumption that all people are either transit captive, or have enough autos to meet household demand. It is apparent that this does not fully describe the population. MIT data shows that there are a significant portion of the population, up to 30%, who are multimodal; they take different modes to work depending on the day. Transit subsides do not serve this group well, because they may not take transit enough to opt in to a transit pass program. Without Universal Access Passes that are paid for on a per-ride basis by the employer, it is expensive for employers to subsidize this group sufficiently to encourage this more environmentally friendly, more cost-efficient commuting.

MIT survey data indicates that the single mode man is a good model for significant populations in urban areas: those who are either transit captive, or have a completely car-oriented work or home location. However, even those who are car oriented may have desire to try transit, but do not find it cost effective under current incentive structures to do so. A significant population of employees at MIT drive to work every day but live within 1/10 or ¼ of a mile of someone who has a transit pass. These people do not have barriers to access transit, and thus have the potential to be multimodal. The population that is currently multimodal chooses this behavior despite policies that encourage them to make single mode choices. The myth of the single mode man shapes the samples that many transportation models are based on, and the transportation policies put in place by the federal government and employers.

1.8 THE MYTH IN MODELS

Transportation mode choice models are most often estimated based on a single-day sample of trips. The implicit assumption is that the trips on that single day are representative of a person's behavior across days, weeks and months. It assumes the same people do the same thing each and every day. Activity based models relax the simplicity of trips by substituting activities, with mode, route, timing, and other transportation choices made to support an activity pattern. However, for the most part, in the US, these too are based on single-day samples. These models can infer intrapersonal variability in mode choice by simulating different activities across days. This simulation is based on single-day surveys. No easy way to validate the simulation exists. It is not a description of actual behavior. Activity based models' accuracy comes from a more realistic and disaggregate description of a single day's activities. Existing models describe the choice of modes, not the choice by the person. They may be closer to describing aggregate reality for any given day, but on the individual level they are still wrong on a weekly or monthly basis.

The goal is not just to describe behavior, but also to change it so as to reduce congestion, pollution, and cost. Large-scale changes are the aggregate of changes that happen at the individual level. This requires better descriptions of behavior by individuals over longer time periods. This thesis follows (Jones & Clarke, 1988), in that "an understanding of variability is a prerequisite for informed analysis of change over time."

1.9 THE MYTH IN FEDERAL POLICY

This myth of the single mode man is encoded in Federal policy on transportation fringe benefits in Section 132(f) of the IRS regulations. Transportation fringe benefits allow commuters to pay for parking, transit, vanpools, and bicycling expenses through their employers, exempting those dollars spent on commuting from Federal income and Federal Insurance Contributions Act (FICA) taxes, and in most cases from state taxes as well. Employer subsidies are also considered non-taxable benefits up to prescribed limits. The Federal government privileges monthly transportation benefits by making it easier for employers to administer programs paid for on a monthly basis. The IRS has interpreted this law on the transit side as requiring that the benefits be provided by distributing transit fare media, unless no such media is "readily available." No substantiation requirement exists when an employer distributes transit passes, and therefore employers subsidize monthly passes, but not per-ride fares. Similarly, parking benefits are simpler to administer, and do not require a bona fide reimbursement arrangement per the IRS rules, if they are provided in kind on a monthly basis.

1.10 The Myth In Employer Benefits

Employers are motivated to attract and retain employees at the lowest possible cost. To meet this goal they generally respond to these federal incentives in three ways: (1) they offer only monthly (as opposed to per-ride) transit passes or parking permits on a pre-tax basis; (2) they allow participation in only one or the other of the programs, not both; and (3) they may subsidize transit passes and parking permits by different percentages and amounts. All of these issues cause employees to allocate their behavior away from their individual first-best solution on any given day. They respond to either-or subsidies that may encourage them to drive more, or walk less, than they otherwise would. These policies also detract from the system optimal solution, whether the system under consideration is the cohort of employees, or the region. If an incentive is only available for driving or transit, a person who must drive sometimes will drive more (or exclusively) in order to "get the most out of" the parking they pay for (or receive free). The result of this is that people have less incentive to optimize their commute mode for their activities during the day.

While employees can still receive both benefits under federal law, most employers require employees to choose between parking, transit, and vanpool benefits. After all, if an employer believes in the single mode man, any employee who wants to take advantage of two different benefits programs must either be engaging in fraudulent or rent-seeking behavior. These policies reinforce the single mode bias, and make employees who prefer to—or are required to—engage in activities that make them multimodal worse off.

The cost of parking is often part of capital expenditures, rather than operating budgets. Thus, the perceived cost of providing that parking is less than actual cost. The allocation of parking subsidies to capital budgets leads to higher subsidies for parking in both total dollar and percentage terms, considering the full cost of providing that parking, including capital and land opportunity costs. Low parking prices reduce the financial costs of driving to work, encouraging employees to consume more "automobiles" in all facets of their lives, because they bear less of the cost. This in turn leads to more demand for parking, and more demand for employers to continue and increase these subsidies. Employer transportation subsidies create pernicious methods for employees to maximize total compensation from their employers, and for employers seeking to maximize employee satisfaction.

1.11 Incremental Change

This thesis has as its goal to affect the processes of incremental change. Universal Access passes originated in part from transit agencies' desire to fill empty seats. In this case any increased ridership means additional operating revenue, since it does not require an increase in service. In applying these programs to areas with transit systems nearer to capacity, such as Boston's Massachusetts Bay Authority (MBTA), in theory there are fewer empty seats to fill. However, given current budget constraints, there is no expectation that these programs would result in additional service. This thesis shows that increases in utilization of available capacity do lead to additional revenue for the MBTA. However, this is not a substitute for additional operating subsidies, or system expansions that increase the reach and quality of transit service. The Mobility Pass and similar programs can help transit agencies increase their operating revenues, but it cannot solve the fundamental operating and capital shortages that these systems face. Employer programs can increase transit utilization, and by increasing individual's exposure to the transit system can grow the constituency to fund increased transit service.

Employers also face political constraints. Parking and transit benefits represent an implicit statement by the employer that they "care" about their employees, among other things. These meanings have remained as the costs of providing these benefits have changed over time. For example as parking was once an inexpensive benefit to provide, and thus it was less expensive for employers to "care." Thus new policies need to fit within historical constraints. This should not constrain the policies considered. It is evident that policies that were rational and directionally correct when implemented, today have effects they were never intended to have. It can therefore be assumed that the same will be true for those policies implemented today. More insight into how people actually behave, especially the existence of the multimodal commuter, permits the design of policies that do not constrain future developments.

Complete mode shift is hard. People base their mode choices on their activity patterns, and vice versa. Changing from one dominant pattern to another is a difficult proposition, made more difficult by the need to make the decision without the information gained by, and reinforcement of, the daily commute. Increasing economic incentives to encourage occasional shift to transit—or at the least removing disincentives keeping people from this behavior—can potentially lead to more long-run commuting changes.

Imagine you live in a city with a five-foot wide crack in the middle. Everyone is on one side of the gap. On the other side of the gap is a guy giving out free $20 bills. Your job is to manage the gap crossing. You charge people $10 to cross the gap. There are two ways to allow people to get to the other side. You can ask people to leap, or you can build a bridge. Leaping seems cheaper, and easier. Lots of people have the proper muscle tone and bravery to make the leap. A cottage industry in springs and long sticks has emerged to help people jump. It seems like it is a sufficient solution, since there are now people on both sides of the gap. You assume that everyone who has not made the leap is doing so because they prefer to stay on their side; it is worth more than $10 to them. This ignores what might happen if you build the bridge. And, it ignores the cost of extracting all the people who have tried to cross the gap and fallen in.

If you build a bridge you both keep those people from falling, and encourage people who would not otherwise attempt it to cross over to the side where they are giving out free money. A "bridge" increases the total benefit to individuals and society, and increases the number of $10 bills you can collect from people. If you are lucky, building that bridge also costs less than extracting those people who have "fallen in."

The "other side" is the world with fewer auto commutes, resulting in less congestion and lower emissions. The high costs of subsidizing parking are the free money that can help subsidize the bridge building enterprise. And the employers are the ones in charge of the gap crossing. Right now. policies make it hard to move from one mode to another gradually, by blending modes over time (partial mode switch). To get to the other side requires a leap.

Reducing the barriers to mode switch by allowing mode blending (partial mode switch) can result in an "everyone wins" situation for the employer, the municipality, the transit agency, employees, and those people who are generally concerned with reducing emissions and greenhouse gases. The Mobility Pass is the bridge to the more sustainable transportation choices that exist on the other side. The Mobility Pass is a Universal Access pass, paid for by the employer on a per-ride basis. This allows for a full accounting of the costs and revenue for both employers and the transit agency. Because it applies across all employees (and students), it allows zero marginal cost access to transit, encouraging those people who currently2 use transit occasionally, but often drive, to use transit more, and those people who never use transit to trial it.

Partial mode switch can be seen as pathway to complete mode switch. The myth of the single mode man implies that only complete mode switch is possible. In this thesis we present evidence that a significant portion of the population is already choosing to be multimodal. Removing disincentives to multimodalism, especially those that encourage more use of more sustainable modes of transportation, should increase the viability and prevalence of this behavior.

1.12 Research Approach

Chapter 2 examines past research in travel variability and the literature surrounding individual's location choices. It incorporates literature on product bundling, behavioral change, and the architecting of the context for choices to establish a strong theoretical framework for the remainder of the thesis. Chapter 3 builds on this framework by examining the history of employer benefits programs and commute trip reduction ordinances, and how they have been manifested in innovative transit and parking programs in Phoenix, Denver and Seattle, among others. These case studies provide lessons on what works and what does not work.

The history of transportation benefits at MIT is presented in Chapter 4. Transportation benefits—specifically parking—have held, and continue to hold many different meanings at MIT. These meanings work with and against each other in the Institute's decision-making structure. Chapter 5 introduces the concept of, and motivations behind the Mobility Pass, and reviews the 5-year-long history of the Mobility Pass proposals at MIT. It attempts to fit the Mobility Pass into the meanings of benefits established in Chapter 4, and predict how it might develop and save money in a climate of economic instability for both the Institute and its employees. Chapter 5 also establishes the policy options analyzed in Chapter 8.

Chapter 6 examines the evidence for multimodality at MIT. It quantifies the behavior that is taking place, takes a cross sectional look at the demographic antecedents of this behavior, and draws conclusions about the impacts of current transit subsidies on mode choice. It also examines commuters' changes in behavior over time, based on panel data from 2004, 2006 and 2008, to see how commute mode variability has evolved on an aggregate and disaggregate level.

Chapter 7 applies a discrete choice model that quantifies the importance of monthly and daily costs of transit and parking to the policy options established in Chapter 5. The model allows prediction of the costs and benefits of these programs for groups of employees at MIT, the Institute, the City of Cambridge, the MBTA, and the region. Chapter 8 draws conclusions on the viability of the proposals presented in the previous chapters, and explores implementation details. Finally, Chapter 9 extends this analysis to consider integrating Universal Access Passes on a citywide level, using Cambridge, MA as a case study.

2 Previous Research

This thesis attempts to connect new information on the variability of the daily commute mode with the need to change transportation subsidy regimes. It draws upon a wide variety of research in transportation related disciplines to inspire its hypotheses. This section begins with a review of the past research on intrapersonal variation in travel behavior. Next, it describes a variety of experiments regarding the rationale behind behavioral change, and the roles of attitude, perception and intention on behavior. It proceeds to the effect of long-term decisions of home and work locations on mode choice. It then reviews the literature on product bundling, both in terms of optimality, and desired purchase behavior. Finally, it looks at the policy design process in terms of a choice architecture, with a focus on libertarian paternalism. Each area of research has concepts that reinforce the others' insights.

2.1 Terminology

The literature on variability in travel behavior is relatively sparse, and the terminology varies greatly. Pas (1987) and Kitamura, Yamamoto, Susilo, & Axhausen (2006) both prefer "intrapersonal variability," to distinguish it from interpersonal variability. While technically accurate, this description seems overly technical. On the other hand, Diana & Mokhtarian (2009) focus on "baskets" of mobility to create synthetic indicators of multimodality. Nobis (2007) distinguishes between monomodality (a single mode), multimodality (multiple modes within a given time period), and intermodality (multiple modes within the same trip). This thesis uses multimodality and intrapersonal variability interchangeably throughout. It also uses "mode bundle," a synonym derived from product literature. (Ben-Akiva & Gershenfeld, 1998) (Adams & Yellen, 1976) If each mode is a separate product, then people's decision to use multiple modes for the commute trip is akin to their decision to purchase multiple products.

2.2 Model Shortcomings

Some people choose different modes on different days. One reason for this is variation in activity patterns; shopping trips, piano lessons, etc. Activity based models will do a better job of replicating these multi-day choices than trip based models, even with single day samples. For example, Ben-Akiva & Bowman (1998) find that the utility of secondary tours has a strong affect on the choice of alternatives in the primary tour, and the complex tours are more sensitive to changes in cost than simple tours. Weather and traffic also affect choice. These, too, can be integrated into trip or activity based models based on single day samples, and then applied across days of the week.

However, this thesis follows Hirsh, Prashkea, & Ben-Akiva (1986) in pointing out that there are some parts of the weekly pattern of trips that are dynamic, and based on choices that cannot be captured on the day level. As they point out, the implication is that both past participation and future plans influence the current decisions (holding household and job locations, and auto ownership constant). The choice made on a single day is one in a series of choices made that week. What I did yesterday, and what I plan to do tomorrow, affects my choice today.

There are three basic reasons for intrapersonal variability in mode choice that cannot be replicated in single-day based models.

(1) People have weekly budget constraints. That is, they may prefer one mode to another, but the preferred mode is expensive. To reduce the total budget spent on travel they use another, cheaper mode occasionally (or, often). There may also be similar constraints in other dimensions, for example weekly time budgets. This is an extension of the analysis in Anas & Moses, (1982).

(2) Some behavior is day of week specific. There are patterns on Monday and Fridays, based to some degree on planned activities (i.e. trips to a vacation home), that vary on the disaggregate level. Single-day samples can correct for this behavior, but cannot replicate it.

(3) Innate preference for variability. The use of alternative specific constants in discrete choice models implicitly and explicitly assumes that, all things being equal, people prefer one mode to another. Probit models, which allow for taste variations between individuals, allow these preferences to vary between people or households. But, they still assume a *ceteris parabus* (all else equal) preference. If there are single mode preferences, then it must also be allowed that some people would prefer to use multiple modes in a week, "for the sake of" variability, or because of unexplained variation in preference.

As Hanson & Huff (1988) conclude, while behaviors are repetitious, daily patterns are much less so. They point out that 10% of people riding the bus on a given day could mean that 10% of people ride the bus all the time, or that everyone rides the bus 10% of the time. This, they conclude, will cloud measurement in a one-day sample. The parameters for a model based on the first behavior and one based on the second will be very different, but the one-day sample implicitly assumes that the first description is true. Pas (1987) comes to a similar conclusion for trip generation. He finds that trip generation models that do not use panel data will have a poorer fit, given that 50% of the difference in trip generation is intrapersonal. Anas & Moses (1982) apply this analysis directly to discrete mode choice models. In their analysis, they rely on the common description of discrete choice: the individual is "a myopic and memoryless maximizer." A discrete mode choice model without panel data assumes that each person makes a new decision each day, without relying on previous days. Anas & Moses (1982) conclude that taking the weeks' decisions as a whole results in better models, in theory. They call the travel patterns of the entire week, a "blending" of alternatives. By blending, there are more subtle levels of substitution, which allows a more realistic calculation of substitution between modes. The choice is not either/or, but also "some of this and some of that." Blending models lead to lower elasticities of demand because of the more closely substitutable choices. No longer must a modeled individual replace one mode with the other for all trips. They can, instead, replace one day of driving with one day of taking the bus. This is not only important for modeling, but a key behavioral insight. Complete change is more difficult than switching to a different mode blend.

2.3 Evidence Of Intrapersonal Variability

It is far from a new insight that people do not travel the same way every day. It does not require a model, but rather simple reflection. The quantification of this variability is still scarce, whether in mode choice, trip generation, or activity patterns. Hanson & Huff (1982) detail three frameworks for examining the day-to-day variability in travel behavior, focusing on variation in mode, activity and time of day. Using the Uppsala, Sweden household travel survey, they conclude that variability does exist, but that it is difficulty to effectively characterize that variability. Pas & Koppelman (1987) also conclude that intrapersonal variability exists. They point to demographic factors as the cause of variability in trip frequency between days. People without role-related constraints or jobs, and those whose daily activities don't require leaving the home, tend to have more variability in trip frequenxy.

Kitamura & Van Der Hoorn (1987) examine the variability in activities in a sample from the Netherlands. They find that there is more regularity than would be expected from an even distribution. This leads to the conclusion that participation in an activity one week is good indicator of the same activity in a given week months later. Their categorization of activities is stable given changes in household size, pre-schoolers, number of cars, and employment status. Thus they conclude the activities are not the driver of week-to-week variability in activity patterns, even if it does drive day-to-day variability. Hanson & Huff (1988) also examine the variability in activity between days and weeks, in this case using combinations of stop characteristics (e.g. mode and activity, or time of arrival and location) to define the differences in trips between days. Unlike Kitamura & Van Der Hoorn (1987) they find that one week does not fully represent 5 weeks of variability in travel patterns. Jones & Clarke (1988), like Hanson & Huff (1982), examine different methods of visualizing and quantifying activity changes between days, and conclude that 50-70% of activities in a given 15 minute period between days are similar. Kitamura, Yamamoto, Susilo, & Axhausen (2006) take a slightly different tack. They use the example of "my child's Tuesday piano lessons" to point out that even if variability is unexplained, it may still be systematic. The variability examined in their study is in departure time, with the finding that one third of this variability is intrapersonal.

The studies presented above are attempting to gain insight into variability at a high level, without holding activities, trip purpose, etc. constant. This thesis diverges from that research by instead examining those trips that share a very exact set of similarities: the same destination for all travelers, and the same origin for each trip throughout the week for each traveler. The focus is only on a single axis: the mode. The question is whether the variability of mode choice within this week is a good representation of the variability over a series of weeks or a year? If it is not, then it is inadequate to compare disaggregate changes year over year, since the random disturbance may outweigh any real changes.

Schlich & Axhausen (2003) conclude that there is more variability in activity patterns in a two-week sample than one-week samples, but that after two weeks there is little additional variability gained by adding days to the sample. This thesis is interested in the variability between days. This requires controlling for the variability between weeks. Chapter 6 examines this issue in more depth as it attempts to determine a baseline for change in behavior over time.

2.4 Quantifying Multimodal Behavior

The German Mobility Panel is a rolling 6-week sample of travel behavior, with participants sampled 3 times over the course of three years. (Kuhnimhof T. G., 2009) The resulting research represents the first real quantification of the inherent variability in mode choice. While their exact results are not transferable to Boston, they do give some indications of the amount and type of variability in mode choice that exists.

As can be seen in Table 2-1, Kuhnimhof, Chlond, & Ruhren (2006) find that variability in occasional use is greater for walking that for other modes, where it ranges from 15-20% above the single day patterns. The expectation is that there will be much less variability for commute trips at MIT. Kuhnimhof, Chlond, & Ruhren (2006) find that for commute trips 90% use the same mode every day. They also find that there is more multimodal behavior in larger cities, and among people below the age of 25. Chapters 6 examines the extent to which age affects multimodality.

Table 2-1. Mode Share Differences Between A Single Day And Week Sample

	Used mode at least once in a single day	Use mode at least once in a 7 day period
Walk	42%	72%
Bicycle	15%	30%
Drive	45%	65%
Public Transit	15%	30%

Source: Kuhnimhof, Chlond, & Ruhren (2006); data from German Mobility Panel

Kuhnimhof & Gringmuth (2009) find that on any given day, slightly more than half of travelers in Germany are monomodal for all of their trips, not just the commute trip. However, in a given week period, 90% are multimodal in their weekly mode choices. Using this same data set, Nobis (2007) finds that 46-48% of people are multimodal within a week, with 10% of the population using both public transit and the personal automobile. However, if multimodal is defined as fewer than 70% of trips on a single mode (in order to examine those people who regularly blend modes) then only 21% are multimodal. 8% of this 21% uses both public transit and drives in a given week. Via a series of logit models comparing those people who are monomodal auto vs. various multimodal groups, she finds that people are more likely to be multimodal if they work, have low car availability, few cars in the household, no children below 6, a high number of trips in a week, and a high income. This thesis investigates these same trends both in Chapter 6 and Appendix 7.

Schlich & Axhausen (2003) make the connection between supply of variability and demand for that variability explicit: "the more variable and complex their behavior is, the more flexible the supply needs to be." Chapter 7 of this thesis proposes means for increasing flexibility in the architecture of transportation benefits, in order to better meet the evident variability in mode choice and encourage more sustainable choices.

2.5 BEHAVIORAL CHANGE

The goal is insight into the antecedents of variability in travel behavior, holding other key variables constant. If some people are already multimodal, can interventions create more multimodality? The literature on mode switch is mostly grounded in a behavioral framework where attitudes and perceptions lead to intentions, which are mediated by conditions, to affect behavior. The main point of contention is whether commute behavior is habit based, or is instead mediated on a daily basis by attitudes, perceptions, and activity variability. If commute behavior is based on habit, then it will be more difficult to change because interventions that modify the attributes of the choice will not be considered on a daily basis.

Pas & Sundar (1995), in their study comparing trips in Seattle, WA to a sample from Reading, England 20 years earlier, find that travel is "not mindless." Activities, routes and modes are chosen on a daily basis. Verplanken, Aarts, & Van Knippenberg (1997) and Garling & Axhausen (2003) address the problem of habitual behavior head on. Verplanken, Aarts, & Van Knippenberg (1997) portray travel as activation of goals (behavior), mediated by the characteristics of the situation - distance, time, weather, available modes, speed of travel, comfort, etc. Behavior is further mediated by the strength of habit formation. Habits curtail the process of gathering information about the characteristics of available options. Garling & Axhausen (2003) portray habits as repeated behavior based on unchanging stimuli. Verplanken, Aarts, & Van Knippenberg (1997) find that "strong habit participants particularly neglected information about alternatives to their habitually chosen option ... habit strength is negatively related to the depth of predecisional information search." This points to the need to increase the information search about the entire choice set. Bamberg, Rolle, & Weber (2003) agree that "strong car use habit makes travel mode choice script-based, so that minimal information is needed to make it." Habit reduces the motivation to process information about public transit, even if there is new information, such as cost reductions. They hypothesize that in the face of an information campaign, attitudes and intentions change, but not behavior.[1]

[1] This may suggest that the real result of the information campaign is to make those who already drive more happy with their choice.

In Verplanken, Aarts, & Van Knippenberg's (1997) intervention, they prompted participants to increase their information search. They found that those people who had strong habits prior to the intervention increased their level of information search when prompted, but soon slacked off, whereas weak habited participants kept up with information search throughout the study period. The implication is that habits can change through an information-only intervention, but eventually those trips return to the norm. One can either conclude 1) that habits are hard to change, or 2) that habits are hard to change without a more significant intervention.

Garvill, Marell, & Nordlund (2003), test a non-monetary intervention similar to Verplanken, Aarts, & Van Knippenberg (1997), under the hypothesis that "the stronger the habit, the less the influence of attitude on behavior," where habit is defined as the frequency of monomodal behavior. Specifically, they test whether increased awareness increases the strength of the relationship between attitude and behavior, whether attitudes decrease the strength of habit, and whether there is a larger behavioral response from those people who begin with a strong car use habit. They conclude that because their intervention was information only, there was little response overall, but slight indications of a stronger response from people with a stronger previous habit. The implication is that to elicit behavioral change there needs to be strong motivating factor. Mokhtarian, Raney, & Salomon (1997), in their study of responses to congestion suggest that desire is a also a pre-requisite. Eliminating a constraint from one alternative, such as reducing the cost of public transit, does not alone cause that alternative to be chosen. Instead, change requires a driver, such as wanting to have more leisure time, or more money to spend on groceries. This might indicate that there is a stronger case for changing the relative prices of modes in order to change behavior during more trying economic times. Fujii & Kitamura (2003) test an intervention of free public transit ticket for a single month, and find that concurrently increasing positive perceptions of the alternate mode, and decreasing positive perceptions of the primary mode, are key to mode switch. This points to a similar conclusion as Mokhtarian, Raney, & Salomon (1997); there needs to be drivers of behavioral change on both the positive and negative side—both "carrots and sticks"—in order to maximize behavioral change.

Bamberg, Rolle, & Weber's (2003) intervention involves both information, and a single day of free transit, for a group of people who have recently moved. They find that there is an increase in positive attitude toward public transit, an increase in subjective norms, and increased perceptions of behavioral control ("It would be easy to use public transit"), in addition to increased intention to use public transit. Those first three antecedents account for 67% of intention, while intention and perceived behavioral control account for 77% of actual behavior at the new residence. They also find that past car use is not an influence of mode choice at the new residence. These results imply that car use is not actually a habit (repetitive activity without considering a change in attributes of the choice set), but is instead mediated by new information. An intervention can make significant changes to behavior during a seducible moment, when other things are changing too.

Bamberg, Ajzen, & Schmidt (2003) also use the behavioral framework of influencing intentions and behavior by intervening at the antecedents—attitudes, subjective norms, and perceptions of behavioral control. They analyze a semester pass program, which requires purchase of zero marginal cost transit for students. Bamberg, Ajzen, & Schmidt (2003) hypothesize that prior behavior is a reflection of past conditions. Thus if these conditions remain the same, there is little motivation for behavior to change. Just because behavior is unchanging does not mean it has come under the control of habit. If this is the case, then changes in attributes of the choice, and new information, will decrease the significance of past behavior. They find that there is an increase in all of the behavioral antecedents, an increase in disposition to public transit usage, and an increase in reported ridership. However, they also find that there is a high correlation of car use during the period before the intervention with car use in the period after the intervention. There are some people whose behavior is more difficult to change. The introduction of a Universal Access pass causes reconsideration of other options, which was helped by the public discussion of the program before its introduction. Habit is essentially meaningless: "even when routine, human social behavior is already regulated at some, even if low, level of cognitive effort, minor events disrupt automatic execution." (Bamberg, Ajzen, & Schmidt, 2003) Their results may not be directly applicable to the proposed changes in this thesis, as the student population they study may be much more sensitive to marginal changes in cost.

Bamberg & Schmidt (2001) study this same intervention in the context of group behavior. They hypothesize that if subjective norms influence usage, and vice versa, then transit usage will increase above and beyond the normal predictions of behavioral change. They find that public discussion does change perceived social norms of public transit usage, and that people did change their behavioral beliefs about public transit based on the Universal Access pass intervention. Furthermore, this intervention changed behavior more in those groups who were against the intervention, because of the significant effect on their perception of public transit. The implication is that any program needs not only to be announced, but to be discussed.

Mokhtarian, Raney, & Salomon (1997) indicate that their results suggest that people perceive strategies to reduce the cost and time of their commute in rank order, based on both cost and effort, so that small changes are adopted first. This ranking is evocative of Anas & Moses' (1982) blending hypothesis for changes within modes. The implication is that structuring any program whose end goal is behavioral change as a series of small steps will be more effective than a "big bang" approach. Rose & Ampt (2001) focus on just that type of "achievable change" that does not require "overnight" changes in lifestyle, but instead incremental reductions in car use. They call this concept travel blending®, defined as (1) thinking about activities and travel in advance, (2) blending modes, (3) blending activities on a single tour (4) making sustainable changes over time. They distributed travel diaries, provided immediate feedback including travel planning based on those diaries, and used a toolkit aimed at increasing awareness of VMT, to influence their experimental group in Australia. This resulted in VMT reductions of 7-10%. Thus, relatively significant reductions in VMT were achieved from an information-only intervention only by focusing on small changes.

2.6 Location Choice

As Weisbrod, Lerman, & Ben-Akiva (1980) note, there is much past research that concludes that transportation has a small, but significant effect on home prices. The implication is that mode choice and location choice are intertwined, to some degree. It is only those people who have recently moved who are in definite equilibrium in terms of their location choice and their desired mode attributes (others may be in equilibrium, or may not). They find for a Boston sample that 20% of all households do, in fact change their location each year, and that 42% move within a 5-year period (45% of those 42% stay within the metro area). Aizcorbe & Starr-McCluer (1997) find that car purchases (used or new) occur on average once every 4.5 years (average car age 8 years, divided by 1.8 cars per household). People change jobs at the median once every 4 years. (Federal Reserve Bank of San Francisco, June 2007) People are rarely in equilibrium in all three of these choices.

Weisbrod, Lerman, & Ben-Akiva (1980) indicate that it is misleading to analyze the tradeoffs for households who have not moved recently. Moreover, movement itself is not costless, and cannot be assumed to be so. This decision is similar, although less costly, for the work location choice. Therefore, there may be a significant difference in mode choice between those people who moved under different conditions many years ago and those who have moved recently. This does not reflect desired behavior, but instead past choices. The implication is that changing mode attributes may bring people closer to their desired behavior in the short term, if they are not currently in equilibrium. In the long term these changes may provide incentive to optimize location based in part on their desired mode and activity pattern, or vice versa. Inasmuch as people adapt to their situations, changing incentives for location choice may lead to changing mode choice.

Ben-Akiva, Bowman, & Gopinath (1996) put a theoretical framework around the combined choice of residential location and mode choice. They argue that short-term choice of activities and scheduling are predicated on long-term mobility and lifestyle choices, including housing, employment, and auto ownership. Mode choice is conditioned on the choice of activities and the allocation of automobiles in the household. Automobile allocation is conditioned on auto ownership. Finally, auto ownership is conditioned on workplace and school location. Ben-Akiva & Bowman (1998) conclude that residential location is conditioned on the activity pattern: “the daily pattern reflects a longer term lifestyle decision.” If this is the case, then interventions that aim for complete mode switch run up against longer term, lifestyle decisions.

This is similar to the conclusions from Anas & Moses (1982) and Rose & Ampt (2001) regarding the utility of smaller changes to mode choice, in this case in order to fit into existing activity patterns. If the goal is reduction in emissions and greenhouse gases from auto usage, then focus needs to be on the commute trip, even though it only constitutes 24% of vehicle hours travelled (VHT). Anas & Moses (1982) indicate that job location is one driver of longer-term choices such as the number of autos in the household and residential location, which in turn influence the activity patterns and mode choice to fulfill those patterns. This thesis focuses on the travel alternatives to MIT from the home location as the driver of behavioral change.

2.7 Product Bundling

Product bundling is a means to extract the consumer's full valuation from a suite of products. Bundling sorts customers into different categories based on their reservation prices Adams & Yellen (1976). To achieve optimality in bundle pricing requires encouraging consumers to purchase products that are not as highly valued by that particular segment. It is "how a single firm, facing segmented customer demand and product specific costs, can determine optimal product line breadth and pricing." Hanson & Martin (1990) and Adams & Yellen (1976) discuss bundling on a number of different levels, including bundling by size, for example different sizes of toothpaste tubes.

Transportation benefits are already bundled, in terms of trips. Monthly parking permits are the purchase of a bundle of 20 (or more) parking spaces, one for each day of the month. Monthly transit passes are the bundle of all trips on the transit system for a single month. Transit trips are also sold in "10 ticket" or other varieties, at a discount; another type of bundle. Both parking and transit trips are often also sold unbundled—by purchasing tokens or putting money on a card in the transit system, or via day rates in parking garages and lots.

Employers are monopoly producers of transportation benefits for their employees. An employee cannot get the same benefits from a different employer when employed by the first. For monopolists, there is always the risk that the producer sells output to the wrong people, or over- or undersupplies goods. (Adams & Yellen, 1976) In transportation, there is the risk that by setting prices the employer has under- or over-priced parking and or transit, and is not selling the right products to the right people. There is pure component pricing (products are sold separately only) in most parking and transit programs. You do not get a discount for purchasing transit and parking together. In fact, for the most part, you cannot purchase both from the same employer. This will mean that some people who might prefer some of both products will not be sold this bundle of goods.

For a monopoly producer, the basic rule of thumb is that pure bundling (products are sold bundled only) is preferred to component pricing if the increase in profits from extracting all of the consumer surplus outweigh the lower profits from less complete exclusion of consumers (preventing consumers from consuming a good that exceeds his or her reservation price). If pure bundling violates exclusion (people can purchase a good exceeding their reservation price), then mixed bundling dominates. (Adams & Yellen, 1976) Mixed bundling is when products are available as both individual products (e.g. daily parking) and bundles (e.g. monthly parking permits). Negative correlation between products means that people are at the extremes of tastes. For transportation, the analogue is that some people like to drive, and some people prefer taking transit. With negative correlation, there is substantial consumer surplus in pure component pricing, which can be extracted in the mixed bundle. (Schmalensee, 1982) Employers often recognize this within the demand for parking by offering both daily parking and monthly or annual permits. This thesis finds evidence of only one example of mixed bundles of transit and parking benefits, the University of Washington (UW), examined in more depth in Chapter 3 and Appendix 5. At the UW an employee cannot purchase a parking permit without getting "free" transit.

With Universal Access Passes and Pay-per-ride programs, there is essentially zero cost to produce the secondary product for the employer, since they only pay if the pass is used. Because parking is an expensive good to provide, often provided at a net loss to the employer, the employee need not have a positive valuation from the transit pass for the employer to get value from bundling parking and transit.

The other reason for bundling is complementarities between products. This yields a valuation of the bundle that is super-additive. (Telser, 1979) Hanson & Martin (1990) further point out that if it costs something to bundle products together, then the bundle actually contains a third product, which is assembly. To apply this to employer transportation benefits, Universal Access passes contain a third product, non-commute trips, which the employer must pay for in order to bundle their employees' trips. If marginal product costs are sub-additive—it costs less to produce the products together than apart—bundling may be necessary to make profits (revenue greater than cost). (Hanson & Martin, 1990). This can applied to monthly or annual parking permits, where it may cost less to manage parking for monthly permit holders than it does to maintain a daily parking system, because of less enforcement, less administration, etc.

2.8 CHOICE ARCHITECTURE

The choices in transportation subsidies are many: to bundle or not bundle; to sell parking daily or in monthly permits; to provide transit pass signup sheets in the HR documents distributed to a new hire; to allow opt-in or opt-out benefits. These are all part of the choice architecture of transportation subsidies. The choice architecture is the "organization of the context in which people make decisions." (Thaler & Sunstein, 2008) People's choices are designed, whether intentionally, or thoughtlessly. Thaler & Sunstein (2008) show through multiple examples that bad choices—choices that do not benefit the individual making them—are often the result of poor feedback. People only get feedback on the options they select, not the ones they do not. This advances the case for more information to make informed choices. But, they point out, too much information also leads to poor choices. The goal is "stimulus response compatibility;" to make the signal consistent with the desired action.

For example, 401k programs where contributions are matched by employers are good investments for employees, even if there is no return on investment, because they increase overall compensation. Madrian & Shea (2001) show that when employees opt in to 401ks, they do so at a rate of 20% in the first 3 months and 65% after 3 years. When they are automatically enrolled and can opt-out of the 401k plan, participation is at 90% after 3 months, and 98% after 3 years. The same program, with a different choice architecture, and signals that are compatible with the desired response, has almost complete enrollment. As another example, Thaler & Sunstein (2008) reference a study on 401k enrollment at a different employer. At this employer there was only 9% enrollment after employees first 4 months on the job. Rather than switching to opt-out enrollment, they designed a form that only required a single set of initials to enroll rather than complicated selection of funds and a decision on the amount of income to deduct. Enrollment increased to 34% after 4 months of employment.

The point is not the methodologies (automatic enrollment, easy defaults), although both are interesting, and may have application for transportation benefits. Rather, the instructive lesson is that choices are designed, whether toward a goal, or without regard for results. These design goals hold true on both an employer and system basis. For employers, they can optimize their choice architecture to encourage employee goodwill or decrease the use of parking. On the system level, if there is a normative judgment that “green” outcomes are desirable, policies that encourage employers to offer more flexible and transit supportive benefits packages can be designed. Both can follow what Thaler & Sunstein (2008) call libertarian paternalist tendencies. They can “nudge” employees and employers to make the decision that is best for them, while not interfering with their right to choose. Thaler & Sunstein (2008) point out that more choices are not necessarily better choices. Choices that reduce emissions, and societal costs, while also increasing (or not decreasing) people’s utility from transportation—better choices—are the point of this thesis.

This thesis proposes a series of programs to change the choice architecture of transportation subsidies that employers offer. MIT is the test bed for the theoretical interventions proposed and analyzed. The current architecture of employer subsidies is a hodgepodge of past decisions, historical accidents, and good intentions. It encourages employees to make choices that are 1) inefficient both economically and environmentally, 2) cost the employer money, and 3) cause congestion and pollution in the localities. The remainder of this thesis details how existing programs work, proposes new possibilities, and predicts how those proposals would work if they were implemented.

3 Transportation Demand Management

Transportation Demand Management (TDM) measures are put in place by employers in order to influence their employees' mode choices, and other components of the journey to work. They are predicated on the assumption that changing the attributes of employees' mode options through incentives can change behavior. Inasmuch as this is true, they also influence the long-term location choices of employees. Alternately, they can be dependent on a concept of equity in results (costs, effects of emissions) between drivers and non-drivers. May be put into place via the federally mandated Congestion Management and Air Quality Improvement Program (CMAQ) that provides funding to mitigate poor air quality in areas that do not attain the National Ambient Air Quality Standards (NAAQS). Commute Trip Reduction (CTR) laws on the local or state level sometimes use CMAQ funding for TDM programs, but often use mandates on employers, without a source of funding to meet their requirements. These requirements range from requiring certain programs for employers over a certain size, such as belonging to a Transportation Management Association (TMA), offering transit subsidies to employees, or requiring specific benchmarks for average VMT or single occupancy vehicle (SOV) mode share. (US Department of Transportation, 2005) They are often imposed by localities on institutions as a condition for increasing density above and beyond zoning designations.

For example the Maricopa County (Phoenix, AZ) CTR program applies to all employers with 50 or more employees, and requires a 10% reduction in SOV mode share per year for the first 5 years an employer is in the program, or maintenance of an SOV mode share of 60% or lower. Non-attainment leads to a menu of measures required to reduce emissions. These measures range from transit subsidies, to Guaranteed Ride Home programs, to what they call Equivalent Emissions Reduction (EER) programs focused on reducing congestion and emissions from existing vehicles. (Maricopa County Board of Supervisors, 1997) The salience to this thesis is the incentives (or requirements) TDM measures provide for employers to reduce the supply or increase the cost of parking, and to subsidize the cost of transit passes.

3.1 The History Of Transportation Benefits Programs

Employer-provided transportation benefits predate the privileged status of transportation fringe benefits in the Federal Tax Code. When the main mode of transportation was streetcars or walking, the initial transportation benefit, in a stylized fashion, was the location of the work site in a convenient place. As the car became more dominant, workplace locations moved away from central cities and easy transit access, and the streetcar network was dismantled, the natural extension of that benefit was to accommodate the new mode: to provide parking.

Up until the Tax Reform Act of 1984, in-kind benefits were not taxable. With wage and price controls in place during World War II, employers could continue to compete for employees with benefits packages. These benefits, especially for executives, turned into a larger and larger loophole. The Tax Reform Act of 1984 was an attempt to control these benefits as a whole. Limits were placed on certain types of in kind benefits that could be provided, while others were exempted completely. Transportation benefits in the form of free or subsidized parking were likely covered in the legislation not because of their inherent value, but for completeness. (Dyson, 2000)

A benefit, even if in kind, has value. One can imagine that taxing a benefit that was free to provide the year earlier would not be popular. Either employers would pass the costs on to their employees, or they would have to pay the taxes themselves. Given these two situations, the Federal transportation fringe benefit carved out an exemption that prevented either outcome - parking costs would be exempted from taxable wages. The Tax Reform Act of 1984 enshrined the tax status of transportation fringe benefits into law, but did not set a limit on the total value of the benefit. (Cordes, Ebel, & Gravelle, 1999) This allowed the eventual imposition of charges for employees to be less painful than that imposition would otherwise have been, since those costs would be incurred on a pre-tax basis.

In 1987 the company TransitChek in New York City introduced a $15 per month tax-free voucher redeemable for a transit pass, under congressional advisement regarding the intent of the Tax Reform Act of 1984. Employers were allowed to offer this benefit in addition to compensation, but not in lieu of compensation. (TransitCenter, 2006) In 1993 the IRS amended the regulatory code and added the so-called Section 132(f), which established the transportation benefits program in a form closer to how it is known today. (Internal Revenue Service, 2009) The initial monthly limits were $60 for transit and vanpools, and $155 for parking, with a provision for cost of living adjustments in $5 amounts. The $60 initial limit provides some insight into the intent behind the monthly caps. It seems likely that they were in place to prevent abuse of the system, but not to reduce their intended use. Almost all urban mass transit systems in 1993 charged a monthly fare well below $60.

Under the Taxpayer Relief Act of 1997, parking benefits were officially allowed to be provided by employees' election in lieu of compensation. When President Clinton signed TEA-21 in 1998, the new law extended the applicability of employee-elected transportation benefits contributions to transit as well. (Linton, 1998) There are no known analyses of the increase in the value of the transportation fringe benefit from this change.

Guidance from the IRS in 2003 clarified that the benefits must be provided in the form of transit pass or voucher redeemable only for a transit pass, unless there were extenuating circumstances that prevented this. The exact language is that a transit pass or voucher must be provided unless it is not "readily available." This language was clarified on behalf of the transit agency's lobbying group, the American Public Transit Association (APTA). Ostensibly, this reduced opportunity for "fraudulent use" with cash transfers. (Department of the Treasury, January 11, 2001)

3.2 EMPLOYER TRANSIT PROGRAMS

Transit Cooperative Research Program (TCRP) 107 provides a wealth of information on implementation of transit subsidies by employers and transit agencies across the country. This section presents only a brief summary of a small portion of this report, as context for the various policy options for MIT proposed later in this thesis.

As shown in Figure 3-1, TCRP Report 107 (2005) reports that the highest revenue and ridership gains for transit subsidies are found in Central Business Districts with extensive, high-frequency, transit service, transit benefits that are fully subsidized by an employer who also has implemented other supportive programs such as guaranteed ride home and route planning, where parking is limited and expensive, and where there are already existing transit riders. This finding is based on a review of programs that are mostly in cities that do not have heavy rail systems. This thesis focuses on the subset of employers who are in areas that already have very high transit mode shares (above 35%), but still have employees who drive often. For the most part, increasing direct transit subsidies at this point are not particularly cost effective CTR measures, because most of the benefits would go to existing transit users, while the decrease in costs are too small to effect complete mode switch for the remaining auto commuters. However, they may still be effective equity measures, depending on how equity is defined, whether that be equalizing the subsidies for modes by the same amount, the same percentage, or some other measure.

Figure 3-1. Factors That Affect Transportation Ridership Levels In Transit Benefits Program

Worksite Location	Automobile-oriented suburb	Small urbanized center / Urban fringe	Central business district
Frequency of Transit Services	Very limited or no service	Moderate service level	Extensive, high frequency services
Type of Transit Benefit	Employee-paid pre-tax only	Employer subsidized	Fully employer paid
Other Worksite Programs	Many competing programs (e.g., rideshare matching and telework)		Transit-supportive programs (e.g., guaranteed-ride and home transit marketing)
Worksite Parking	Free, plentiful parking	Employer-paid parking	Expensive, limited parking
Existing Transit Users	Virtually none or nearly all		Some existing users
Change in Transit Ridership	**No Change**	**Moderate Increase**	**Large Increase**

Source: (TCRP Report 107, 2005)

TCRP Report 107 (2005) reports on three other programs—beyond straight transit subsidies and vouchers—that employers offer throughout the country: Universal Access Passes, Pay-per-ride cards, and stored value cards. They do not report on parking programs, such as parking cash out, which are covered later in this chapter. These programs are described in the next three sections.

3.2.1 UNIVERSAL ACCESS PASSES

Universal Access Passes are usually held up as a less expensive means by which employers can provide transit benefits for all of their employees—including people who regularly drive—and thus affect mode shift. In these programs, the employer is obligated to purchase and distribute a monthly or annual pass to all of its employees, but can choose to pass on those costs however it prefers. The price paid for those passes by the employer is based on total anticipated usage of transit by all of its employees. On a per employee basis, the price is much lower than the "retail" price for a monthly or annual pass. Location is often, although not exclusively, used as a proxy for actual mode share: areas well served by transit have a higher price per person than those less well served. Because actual usage is uncounted, employees selling passes, or giving them to spouses, may escape reimbursement. To counteract this behavior, passes often contain a photo, or take the form of stickers placed on existing employee ID cards. Money spent by employers and employees on these programs qualifies as a tax-free transportation fringe benefit. Denver's EcoPass, explored in more detail in Appendix 4, is perhaps the most well known of these programs, and ranges in price from $31 to $279, as of 2003, as opposed to annual fares of $420 to $1,260. Other known areas with active programs are San Jose, Portland, Seattle, Minnesota, Salt Lake City and Rhode Island.

Because these programs are usually designed to be revenue neutral for the transit agency, estimating expected mode shares is simple division of the annual fare price by the Universal Pass price. In Denver, this implies mode shares at employer sites of 7-25%. These programs have often also been put in place in University settings, for students, staff, or both, in which case they are commonly known as University Passes.

Brown, Hess, & Shoup, (2001) summarize the benefits of these programs quite succinctly for universities in low mode share areas: they reduce parking demand and increase access, while improving transit service. This then helps universities attract and retain students by lowering the perceived cost of attending the university, and encourages student mobility without the negative consequences of driving. Brown, Hess, & Shoup (2001) also focus on the three common choice architectures for these programs: opt-in—where people are required to sign up, opt-out—where people participate by default but can choose to cease participation, and universal coverage—where all members of the covered group are required to participate. As they show, the first of these can suffer from what they term "adverse selection" wherein only frequent riders are enticed to participate, driving up the cost per rider significantly. Opt out provisions can reduce but not eliminate the problem of adverse selection. They focus primarily on those programs that provide universal coverage, as it avoids the problem of adverse selection. Universal or required coverage has the lowest cost per rider, as it compels even those who never take transit to participate. Universality is, in a sense, a tax on externalities. People who do not use transit see benefit from decreased congestion, increased availability of parking, etc. Therefore, requiring participation in institutions that are large enough to internalize these externalities, may be fair. However, it can be difficult to impose on employees if a new payroll deduction is required.

3.2.2 Pay-per-ride

Pay-per-ride cards reduce the uncertainty for transit agencies regarding total fares received. In these programs the employer, in concert with the transit agency, provides employees with a card that can be used for transit service. The employer is billed based on actual usage by their employees at the end of the month. The employer can fully subsidize this service, charge a flat monthly fee, or subsidize part of each fare. Valley Metro in Phoenix is the most well known provider of this type of card. They bill employers for their employees' usage, capped at the monthly pass cost per employee. This guarantees in theory that the program is revenue neutral for the transit agency, and revenue positive if it increases usage. In practice it is more problematic, as shown in detail in the Valley Metro case study in Appendix 3. Because of post billing based on actual usage, the employer bears the brunt of any lost cards, sharing with other household members, or other unintended uses. Employers have the opportunity to prevent misuse by combining the fare media with an ID card that the employee carries with them. (TCRP Report 107, 2005)

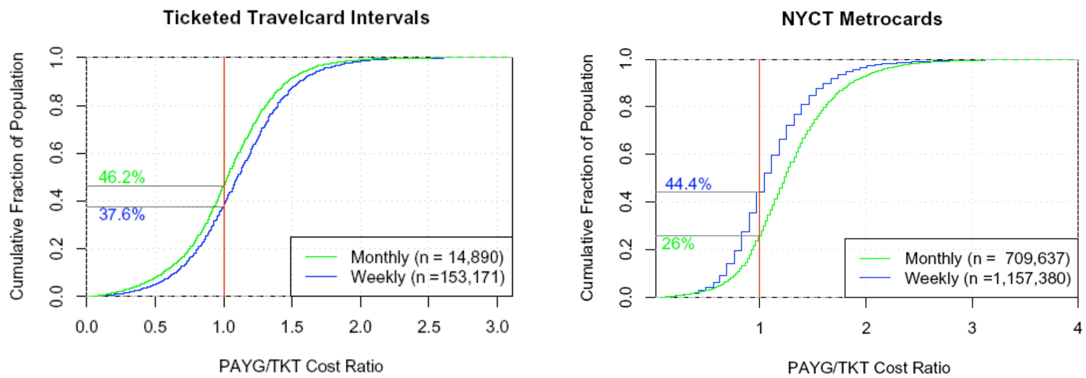
If the transit agency includes a monthly cap and employers subsidize the costs there is a risk of revenue loss. If employees who previously purchased monthly passes used less than the monthly pass price, then the value of the fares they did not use was still collected by the transit agency. A cap eliminates that revenue from the transit agency. In essence, a monthly pass is a bet each month by the employee that they will use more than the value of the pass. If they win, they ride free for all trips above the fare value of the pass. If they lose, the transit agency receives the difference.

In London's subway, the Underground, the transit agency wins this bet 48.5% of the time for monthly passes, and 42.1% of the time for weekly passes, as can be seen in Figure 3-2[2]. The amount of revenue in London lost vs. pay-per-ride fares from people who travel more than the cap is approximately 10% of total pass revenue. The amount of revenue collected from those people who use the pass for fewer trips than the value is approximately 7% of pass revenue. Thus, monthly passes in London would result in a 3% revenue loss vs. a pay-per-ride system without capping. If ridership beyond the cap is off-peak, and is at least partly induced by the lack of marginal cost, the cap may well be a rational and cost effective benefit. In

[2] With an unknown margin of error due to the methodology for calculating the prices, due to difficulties in collecting transfer information. See Frumin (January, 2008).

New York City, the transit agency wins the bet 44% of the time on a monthly basis, and 26% of the time on a weekly basis.

Figure 3-2. Cumulative Distribution Function of Monthly and Weekly Usage of Transit Passes in London & New York City



Source: (Frumin, 2008)

3.2.3 Stored value cards

Stored value cards are similar to pay-per-ride programs, except that they are billed in advance, and are not unlimited. In these systems, the employer adds a set amount of value to an employee's fare media per month. The employer can offer a flat subsidy, or offer fares at a set discount. In less advanced systems these often take the form of 10-ride tickets. Where transit agencies have stored value, refillable fare media, these can be automatically refilled each month without interaction with the employee. This is the case with WMATA's SmartBenefits program. These programs are much less common.

3.2.4 Measuring Success: Defining Revenue Neutrality

In evaluating the success of Universal Access programs, this thesis makes use of a concept of revenue neutrality. Because these programs use innovative payment methods, what seems relatively straightforward to measure is not as simple as it first appears. The minimum definition of revenue neutrality is that these programs should result in the transit agency garnering the same amount of revenue as they otherwise would from existing riders. These existing riders include not only those people who currently pay for their transit fares through their employer, but also those riders who purchase transit passes or per-trips fares directly from the transit agency. Because there is usually little information on ridership by this second group, there is room for interpretation even in this definition. Even if ridership is known, the type of payment for these riders is unknown. Prices differ for monthly pass purchases and per-trip fares. There are additional complications of peak and off-peak fares in some cases, or other price reductions, such as the mode of travel (Commuter Rail vs. bus vs. subway vs. light rail).

Moreover, the goal of these programs is usually to increase ridership. The question is then whether a definition of revenue neutrality should include the revenue that would have been collected from those net new riders. If the program "fills empty seats" without an expansion of service, then it is the position of this thesis that those net new riders should not be considered as effecting program revenue neutrality. On the other hand, if service increases are required, the imputed farebox recovery of that increase in service should be considered as part of the program cost.

3.2.5 Program Results

The effectiveness of these programs in increasing transit ridership and encouraging mode switch depends on whether the employer or the transit agency is the one providing the numbers (TCRP Report 107, 2005). Proposed measurements include awareness, employee participation, travel behavior changes (new transit trips, mode share, vehicle trip rate and vehicles per commuter), transit agency impact (ridership, revenue, and cost), and regional impact (travel and emission based on mode switch, trip length and transit access). Generally, TCRP Report 107 (2005) found that urban areas see a higher total increase in participating employees, whereas suburban areas see a greater increase in the percentage of employees participating, since they are operating from a lower base. These results may be skewed because most of the cities surveyed were lower density, or smaller cities without extensive rail systems. Ridership increases ranged from 5-25%, whereas revenue increases ranged from 5-40%. No transit agency reported decreasing revenues because of employer subsidy programs. However, no agency actually estimated what their revenue would be without a Universal Access program.

Based on TCRP Report 107 (2005) and numerous conversations with administrators of these programs at transit agencies, tracking the cost implications of Universal Access programs is difficult. Because the fare media is usually "flash passes," there is no way of tracking individual fares, and thus attributing rides directly to the program is next to impossible. Transit agencies and employers therefore both need to take it on faith (or do extensive studies) that these programs are cost and revenue effective. Thus, although Universal Access Programs are designed to be revenue neutral, they may not be. Without Pay-per-ride billing, complicated pricing structures are needed to maintain a balance between attracting employer participation and recouping fare revenue. These pricing structures include 5-year contracts with built in annual increases (Metro Transit, MN) and biannual surveys (King County) for programs that are individualized for the employer. This often results in splitting the difference between the employer and the transit agency for any increase in usage. The transit agency has more revenue than they would without the program. On the other hand, programs based on set pricing for an area based on service availability or some other metric are likely even worse in terms of revenue neutrality. Those employers with higher mode shares than the projected cost for the area have a greater incentive to participate, both for strict cost reasons, and because there is more employee demand. Those employers with lower than average mode shares for the area have less incentive to participate unless mandated, since the program is not as cost effective for the employer. Thus, without ridership increases, even without increasing service the transit agency can see less revenue not only in per-rider, but in net terms.

Ecola & Grant (2008) find that employer pass programs were responsible for 30-40% of ridership growth at selected agencies between 1997 and 2001. In Denver 24% of EcoPass riders were new riders. These programs represent up to 20% of total agency revenue in King County, WA and Minneapolis / St. Paul, MN. (Personal Communication with Metro Transit Minnesota, 2009) The marketing and administration budgets represent up to 2% of revenues from these programs, with exceptions on the high end. The cost to administer Valley Metro's Pay-per-ride program in Phoenix is upwards of 10% of program revenue. It should be noted that marketing and administration may have positive effects on the perception of transit in the area, and thus should not be considered deadweight loss.

3.2.6 Incidence of Benefits

When initial transit mode shares are high, the benefits of any employer program accrue predominantly to the existing transit riders. There is some evidence that existing transit riders increase the frequency of their travel, by between 4 and 25%, depending on the reporting agency and time period. Some of these are non-commute trips, especially in areas with more extensive rail systems, such as New York City, according to TCRP Report 107 (2005). Incremental non-commute "free" transit is an additional benefit of these programs, that may be reflected in employee satisfaction. Employer subsidies increase employee participation to some extent, but are not close to fully elastic. This means that increases in subsidies are more expensive per net new rider than the subsidy programs were to initiate. Costs are incurred for both the existing and new participants, but there are lower ridership increases than in the initial program.

There is also some evidence that supporting programs, such as Guaranteed Ride Home, shuttle systems, bike parking and showers, etc., do increase the effectiveness of transit benefits. In Southern California, in areas with very low initial transit mode shares, the existence of supportive programs increased transit usage by approximately 2 employees per 100. (TCRP Report 107, 2005). This is similar to findings in Appendix 5 for the University of Washington, where the Guaranteed Ride Home program is used by fewer than 1 in 150 employees annually, but the benefit is perceived as important. (University of Washington Commuter Services, 2007) Rosenbloom & Burns (1994) report that transit subsidies may see a gender inequity in implementation. Women are more likely to drive to work because of family obligation or perceived safety, at all but the highest level of incomes, where men and women are similar in their use of the auto. These equity considerations need to be weighed against the subsidies for parking. This is explored in more depth in section 3.3.

3.2.7 Universal Access Programs at Universities

Because Universal Access passes have mostly been put into place in low transit mode share areas, their traditional funding has come almost exclusively from employers. Brown, Hess, & Shoup's (2001) seminal work on Universal Access Passes at Universities focuses on areas that have relatively low transit mode shares. For example the University of California San Diego averages only 8 unlinked trips per person per year—the equivalent of a less than 2% mode share—and thus they were able to implement a program that cost only $5 per student per year as of 2001. In areas where transit mode share approaches 40%, common in urban campuses in cities with a heavy rail system, such as Boston, New York, or Chicago, the number of annual unlinked trips per person can be expected to be between 175 and 200. At a full fare of $1.70 (the fare in Boston) this would mean an annual fee of between $300 and $350. Applying student results to employees is a less than perfect comparison. With that in mind, 100% subsidies are less viable for all but the most environmentally oriented (or parking constrained) employers in medium to high transit mode share areas. In this context, employers must co-ordinate their parking policies with their transit policies in order to provide a viable transit benefit: such a program would not work as well financially for employers if parkers were allowed to forego participation.

Universities are natural "laboratories of innovation" according to Balsas (2003). Both because of their missions, and because of their large campuses, they can and have served as places to test and implement alternative transportation demand strategies for their regions. Balsas compares TDM strategies at 8 universities. He finds that these universities have been able to decrease SOV travel while increasing population and employment by using strategies such as Universal Access Passes, free transit trials, and Parking Cash Out programs like Stanford's "Clean Air for Cash" which compensates employees for not purchasing a parking permit.

In Brown, Hess, & Shoup (2003) the authors evaluate the BruinGO service, a Universal Access pass implemented at UCLA. They conclude that it increased transit mode share by up to 11 percentage points, and decreased solo driving by up to 8%. They found that the fare elasticity of transit demand is -0.28 and the cross price elasticity of solo driving with respect to transit fare is 0.1, in the first year after implementation. Because there is a waiting list for parking, these elasticity measures should be taken with a grain of salt. Parking and transit usage are not purely reactive to price. Instead, they interact with the regulatory regime, that assigns people to park in inconvenient locations, or does not allow the purchase the parking permits subject to conditions of seniority, demonstrated need, etc. This program was funded by daily parking fees and monthly parking permits, and does not assess any additional costs. The relatively low transit mode share at UCLA makes this possible, but these costs are likely to be significantly higher in higher transit mode share areas. They also indicate that one of the benefits is non-commuting usage. At UCLA the perceived cost of this additional benefit is next to nothing, since non-commuting usage is low.

For the transit agencies studied by Brown, Hess, & Shoup (2001) the university is often their largest customer. Thus, their participation can be a significant portion of the local transit agencies revenue. In this context, and with low mode share to begin with, the transit agency has incentive to give a "good deal," reducing the average fare in exchange for double or triple the volume. In more established urban systems many transit agencies already face congestion and crowding issues, and have significant constraints on providing any fare discounts that are not available to the general public because of equity issues. The "big customer discount" is not only unlikely to materialize; it may be perceived as against the transit agencies interest. If the political will exists, then attracting riders is within the mission of the agency, even under revenue reductions. If the political will and budget do not exist to increase service, the transit agency has an incentive to add customers only when they are revenue positive. Theoretically they look better when there is excess capacity, but since transit agencies are unlikely to add service, any ridership increases beyond capacity are likely to result in overcrowding during peak periods, not increased service and costs to the transit agency.

3.2.8 Issues with Universal Pass Programs in High Transit Mode Share Areas

Employers have willingly absorbed $50-$100 per employee per year to provide transit passes in low mode share areas. The value inherent in providing these passes—including meeting the required provisions of local TDM programs and a "green aura" designation—are real net benefits that help attract a talented work force. However, the costs are not trivial in higher mode share areas. Because these passes are designed to be at least revenue neutral for the transit agency, they must also cover the revenue that the transit agency receives from employees who do currently participate in their employer pass programs.

As indicated earlier, in high transit mode share areas transit fares per employee can easily exceed $300 annually ($25 per month) and perhaps even approach $50 per month. In order to implement a Universal Pass for its employees in these areas an employer must then decide whether (1) to absorb a substantial transportation subsidy increase or (2) pass along some or all of its employees' costs of transit usage on an equal basis across its entire employee base. Furthermore, where transit mode share is high (i.e. population densities are relatively high), there may be a significant contingent of people who walk or bike to work. While many of these people may use transit occasionally for non-work purposes, if the costs of a Universal Access Pass are distributed equally across all employees, some people in this group may perceive that they are contributing more money to these programs than they receive in benefits. That is, they may perceive that they are "subsidizing" other employees' regular transit use, while not adding to an employer's cost by using subsidized parking or needing a transit pass for the commute to work. Although even pedestrians may benefit to some degree from less local congestion, it is unlikely that avid walkers or bicyclists will perceive a net advantage after paying for a Universal Pass. Similarly, some employees have no reasonable choice other than to drive to work alone and park (due to their home locations or activity patterns). They will likely be upset with absorbing another $25 or more per month to receive a transit pass they may never use. This is the case even if they are the disproportionate recipients of expensive free or subsidized parking.

3.3 Parking Programs

Because parking subsidies and programs vary between employers, from free parking, to monthly permits, to daily pricing, this thesis examines particular parking programs in more depth in case studies in Chapter 4 and Appendix 5. For now, a review of the most common elements of these programs is in order. "Free parking" is usually only provided by employers in areas where the cost of building and maintaining that parking are relatively low, or if it is packaged with the leasing of office space. It is a bundled good. Parking is bundled with employment. Nationwide, 66% of all employees have free parking. (Litman & Doherty, 2009) These are usually in areas with ample free space for surface lots, and little pressure for expansion of alternative land uses. Per Table 3-1, the estimated monthly cost, including operation and maintenance, for this type of space is $56, or $74 if there are minimal costs for land. Operating expenses alone average $450-$600 per space per year, independent of debt service on the construction of those spaces. (Litman & Doherty, 2009)

Table 3-1. Estimated Monthly Parking Costs By Lot Type

	Construction Cost*	Land Cost*	Maintenance Cost	Total Cost
Surface Lot	$0	$75-$240	$40-$50	$115-$280
3 Level Parking Structure	$122-$241	$25-$80	$40-$50	$187-$371
Underground Garage	$482-$723	$0	$40-$50	$522-$773

* Construction and land costs are converted to monthly costs at a 5% rate over 40 years (the usual lifespan of a garage)

Parking price elasticities with respect to auto vehicle trips range from -0.1 to -0.3 depending on demographics, location, etc. The imposition of charges on parking reduces SOV commuting by 10-60% in urban areas, but there is little research on the conversion of charges from monthly or annual permits to daily charges, in combination with transit benefits. (Victoria Transport Policy Institute, 2008),

Employer parking subsidies are often significantly higher in total dollars per person than transit subsidies (at MIT they are almost triple the amount, $100 per month higher on average). One reason is that the cost of providing parking is often derived from the ownership of real property, which also increases in value. Thus employers may see parking subsidies as an investment rather than a cost. This is in contrast to transit subsidies, which are recurring monthly costs paid to another agency. They cannot be recovered and do not provide potential future "value" to employers. For subsidized parking lots the moment of truth comes when the lot has to be redeveloped in order to capture its increase in value.

For many smaller employers, or for remote locations from the main campus for larger institutions, parking is tied to the lease of a building, and cannot be disposed of separately. In this scenario there are fewer options for controlling parking costs, if the lease cannot be renegotiated. That is, there is no opportunity for the employer to save on parking costs, even if parking demand significantly decreases, unless there is high demand for parking from other tenants at the same site or nearby sites.

While this may be the case in the short to medium term, in the long run everything is negotiable. In this case, it may behoove the institution to implement a change in policy prior to lease renewal, and use the lowered demand for parking to enhance its negotiating position. For larger institutions, leases are often staggered, and thus only a portion of the savings associated with these programs may be actualized before all of the leases have been renegotiated. There are additional institutional factors that way on these decisions, including whether and which parking costs are included in the capital and operating budgets.

3.3.1 Parking Cash Out

In parking cash out programs, employees are offered cash instead of the subsidy amount of their parking, if they choose not to park. These programs have mostly been implemented in California and western cities and towns. California's Assembly Bill 2109, enacted in 1992 (California Legislature, 1992), requires that employers with more than 50 employees located in state air quality non-attainment areas offer parking cash out to their employees. The law requires that this subsidy amount be "the difference between the out-of-pocket amount paid by an employer on a regular basis in order to secure the availability of an employee parking space not owned by the employer and the price, if any, charged to an employee for use of that space." It exempts parking spaces that are not paid for separately by the employer (bundled spaces). The cash allowance is taxable, unless it is spent on qualified transportation benefits, as part of the federal program. There is no data on compliance with the law. Case studies show that implementation of this program has reduced SOV mode share by 15-36%, independent of the total subsidy amount. (Shoup, 1997)

In areas with high SOV mode shares, this program makes a good deal of sense as a measure to reduce parking demand. It is has at most modest costs to the employer, and may result in lowering the cost of providing parking. (California Air Resources Board, 2002) In areas with low SOV mode shares, the program is very expensive. Consider an employer who subsidizes parking $100 per month, and transit $50 per month. There is a mode share of 50% for each mode. As per California law, employees cannot be excluded from claiming park cash out on the basis of not currently parking. Parking cash out is costless to the employer for the 50% of the population who parks, but costs $50 per employee who currently takes transit. The parking subsidy, which is a potential cost for the employer for the entire employee population, becomes a real cost. In this example, it raises the per employee benefits (no longer a transportation subsidy) from $75 to $100. At MIT, approximately 40% of employees drive, 40% take transit, and 20% walk, bike, or are dropped off. The subsidies for parking are closer to $150 per month, and average $45 per month for transit. In the current situation, the average cost of the transportation subsidy per employee is $78, whereas in parking cash out it would be $150, an increase of almost 100%.

3.4 Intersection Of Transit & Parking Policies

In lower transit mode share areas employers may be motivated by environmental concerns or state or local regulation to reduce SOV travel. The high cost of providing parking becomes more important in the denser areas associated with higher transit mode shares. Because land tends to be at a premium, it costs more to provide parking, whether that cost is the opportunity cost inherent in surface lots, or the real cost of constructing or leasing spots in a garage. Assuming some level of subsidy for parking (that is, the employer charges less per space than it costs them to own and operate or lease), a decrease in the number of drivers on a daily basis means a potential real dollar savings for employers. Brown, Hess, & Shoup (2003) point to how Universal Pass programs are complemented by daily parking fees, in that they impose a marginal cost on parking at the same time as the Universal Pass removes it for transit usage. The University of Washington implemented a program combining parking and transit pricing in 1991, called UPass, analyzed in more depth in later in this Chapter. In brief, they give a "free" transit pass to employees with a parking permit, but otherwise run an opt-in program. Therefore coverage of all employees with motorized commutes is complete.

3.5 Case Studies

Appendices 3-6 contain case studies of selected localities' experiences with Universal Access passes and other innovative Transportation Demand Management programs. These case studies cover:

1. The impact on transit agency revenue and employer adoption in Phoenix's Pay-per-use program, the Platinum Plus card (Appendix 3).
   (2) Insight into how a Universal Access Program works outside of the University context, with Denver's EcoPass program (Appendix 4).
2. The effects on parking demand and transit agency revenue of King County Metro's FlexPass program and the University of Washington's UPass program (Appendix 5).
3. Lessons regarding political issues and implementation practice from other Universal Access Programs in Berkeley, Portland, and Minneapolis/St. Paul (Appendix 6).

The results of these case studies are instrumental in designing any program that is positive for employees, employers, and transit agencies.

Phoenix's experience with a Pay-per-ride employer programs demonstrates that:

1. It is plausible to implement a pay-per-ride system, with monthly caps. While this seems overly simple, it is important to establish technical feasibility. Phoenix has had an operational system for 18 years, prior to the implementation of SmartCards. It has continued this system as it has introduced SmartCards. There are future opportunities to track individual usage.
2. Pay-per-ride revenue loss from capping at the monthly transit pass for existing riders is definitely less than 20%, likely less than 10%, and possibly less than 5%. Increased ridership likely offsets this revenue loss.
3. Commute Trip Reduction programs provide incentives for employers to provide transportation subsidies. There are some indications from this case study that these programs are effective in reducing SOV mode share.

4. It is easier for a transit agency to implement a program, than to track its success. Metrics for success, such as net new riders, or revenue neutrality need to be in place to track the effectiveness of such programs.

Denver's experience with the EcoPass program provides four lessons for the design of a revenue neutral program that increases ridership in a high transit mode share area:

1. Universal Access programs can increase ridership in areas that already have high transit mode shares.
2. This ridership increase is quite variable between companies. The subsidy amount is likely related to ridership gains, but it is unclear the extent of this relationship.
3. Flat pricing based on mode share in the surrounding area for Universal Access Passes, no matter how well designed, is always likely to result in some lost revenue for the transit agency. Lag is likely significant, and net revenue compared to the pre Universal Access pass case on a per employer basis is definitely not upheld, even if it might be on a program level. Self-selection, especially among smaller employers, also threatens revenue in a flat price regime. Increasing ridership makes up for much of these losses.
4. Without actual measurement of current ridership and new ridership, it is hard to measure success. Without measurements of success, any changes to pricing become controversial.

The FlexPass and UPass programs at King County Metro Transit in Seattle and the University of Washington provide six key lessons for the design and implementation of an innovative transportation subsidy program:

1. Universal Access in combination with parking pricing is cost effective, with a benefit/cost ratio of at least 5:1 over a 15 year period for the University of Washington, in an area with already relatively high transit mode shares. The benefit/cost ratio is likely higher for employers who build underground rather than aboveground structured parking. As University Transportation Systems Manager Peter Dewey put it:

    > "The program has allowed us to minimize the use of our parking facilities. We currently have 12,000 spaces, fewer than in 1983, despite 8,000 additional people. Without vigorously managing our parking and providing commute alternatives, the University would have been faced with adding approximately 3,600 parking spaces at a cost of over $100 million. With fewer cars on campus since the inception of U-PASS, the University has created opportunities to make capital investments in buildings supporting education instead of structures for cars." (King County Dept. of Transportation, 2001)

2. Any program that changes existing transportation subsidy programs requires support both within the transit agency and by employers' top management.
3. Parking fees are both a funding source and an additional disincentive for SOV use.
4. Including a "free" transit pass for parkers, and daily parking for Universal Access pass holders, allows individual commuters to act upon their desire for more flexibility in commute options. This increases transit ridership, even among those who never used the transit system previously. As (Williams & Petrait, 1993) say "people cannot commute the by the same mode each day."
5. Universities are a good proving ground before extending the program to other employers. Because of their large size, Universities are able to internalize of some of the externalities of SOV commuting.

3.6 CONCLUSIONS

This chapter finds that Universal Access passes and the pay-per-ride variant are effective mechanisms to increase ridership and revenue for transit agencies. When combined with parking policies in a single, integrated benefit, they have also been shown to be effective in reducing auto usage, resulting in decreased costs and an increased ability to meet and surpass Commute Trip Reduction goals for institutions. However, data to measure the accuracy of these programs on a disaggregate scale is scarce at transit agencies and within employers. Thus while these programs seem to be successful, the extent of this success is difficult to pinpoint. Moreover, because of the lack of means to measure usage accurately, program costs tend to be based on area mode share or surveys. Both of these provide directionality for pricing, but not precision. The increasing prevalence of smart cards, and the resultant ability to charge based not on estimates, but on actual fares, may permit the benefits of these programs to be measured with less uncertainty, allowing them to appeal to more cities and more employers in the near future.

4 TRANSPORTATION BENEFITS AT MIT

The direct effect of employer benefits programs are payments in lieu of increased salary. But they also signify the employer as beneficent provider, a sort of *in loco parentis* for their employees. The initial decision to provide benefits is "easy." They are cost effective because of the federal tax code on fringe benefits, which give them significant tax advantages. As costs increase, the decision to continue these benefits conflicts with the desire to control costs. In this context, controlling costs is a proxy for furthering the mission of the Institution.

The conflict between the cost and cost effectiveness of these programs vis-à-vis wages, the direct benefits they provide to employees, and their meaning prevents employers from acting as strictly economic, "rational" actors. The remainder of this chapter attempts to understand the decision to continue benefits that are not cost effective for MIT. The hypothesis is threefold. 1) The decision to begin providing these benefits was strictly rational in economic and "mission" terms when they were initiated. 2) These benefits have accreted layers of meaning over time that they did not—and were not intended to—have when they were initiated. 3) Despite the fact that they likely would not be re-initiated if they did not already exist, their continuance is rational because their removal would indicate that the MIT no longer "care for" their employees. This is quite reminiscent of Lindblom's (1959) concept of policy formulation as "muddling through;" a series of small changes based on limited information about the implications of each decision. The crux of making changes to these programs requires replacing not only the economic benefit, but also the meaning that benefit has accrued.

This chapter begins by establishing the transportation context of MIT, including its accessibility to MBTA transit services. It then takes a brief look at the institutional structure of MIT and its organizational mission. It concludes by examining five decision points:

1. The decision to expand campus facilities and build new underground parking garages;
2. The effect of the recent pay freeze for 50% of employees;
3. The continued decision to increase parking prices by 11% across the board annually;
4. The perception of transportation's contribution to emissions on campus as part of the Energy Initiative; and
5. Two recent initiatives to change the shape of transportation subsidy programs.

4.1 BACKGROUND

MIT's main campus, located in Cambridge, MA across the Charles River from downtown Boston, serves as a base for approximately 8,000 employees and 10,000 students. MIT owns just over 4,000 parking spaces, and leases approximately 900 additional spaces in surrounded parking lots. MIT is well served by the

Massachusetts Bay Transportation Authority (MBTA). There is reasonable, but not great access to the MBTA Red Line at the Kendall Square and Central Square stations, very good access to the Route 1 and Route CT1 buses running on Massachusetts Avenue and stopping at three locations on campus and to the CT2 on Vassar Street, the 70/70A in the Northwest Campus, and moderate access to routes 64, 68, 85 serving the East Campus. MIT also has access to major commuter rail stations in Boston; North Station via the MIT-assisted EZRide private bus shuttle; South Station via the Red Line, and the Fitchburg branch via a transfer to the Red Line at the Porter Square station. (Greenbaum, 2001)

The MBTA is the 5th largest mass transit system in the United States. It has a fleet of 1,017 buses on 183 routes, 4 subway lines, and 13 commuter rail routes covering 8 fare zones. In 2006, average ridership was over 1.1m trips each weekday. (Massachusetts Bay Transportation Authority, 2008) In Cambridge, transit journey to work mode share was 28.9% in 2005. (U.S. Census Bureau, 2007) The MBTA charges $1.70 per subway trip and $1.25 per bus trip if users have a CharlieCard (smart card) and $59 for a monthly LinkPass that covers travel on both buses and the subway system. The MBTA also offers college and university students an 11% discount if they buy a semester pass, and maintains a corporate pass program, which helps to facilitate employers' federal transit benefits programs. The MBTA rolled out the CharlieCard smart cards for buses and subways along with a fare restructuring and increase in January 2007.

4.2 HISTORY

This description of the genesis of transportation subsidies in Section 2 also seems to have held true at MIT. The parking benefit never "began." MIT, as it developed, was located in a relatively industrial area. Parking was not a significant cost; in fact it was not a cost at all. MIT owned land that was unused. In this "state of nature," providing spaces for parking meant paving unused areas for surface lots. Spaces were assigned so as to prevent overcrowding in any particular lot, but supply was not constrained, nor was it expensive to expand. One can imagine the logic of providing parking being something like "People want to get to MIT. The car is a quick way for them to get here. It costs us almost nothing to provide parking. Let's provide parking." Moreover, it indicated MIT's willingness to provide whatever was necessary to ease their employee's journey to work. It was likely during this period that the egalitarian ethic of prohibiting reserved spaces was instituted. There were enough spaces close to office locations that little demand for parking was unmet. The meritocratic MIT ethos was not in conflict with supply constraints, and thus could prevail. As new people joined MIT, the existence of free parking de facto affected where they chose to reside. That is not to say it was a conscious decision, but that the very fact that it was unconscious was the root of its significance. Parking was assumed to be free, or nearly so. That it would ever change was not an option to be considered

The growing use of the automobile first appears to have disrupted this state of nature at MIT in 1950. The installation of parking meters on Memorial Drive, adjacent to the MIT campus, created “overwhelming” demand for parking on campus. This forced the administration to disseminate stickers indicating who was allowed to park on campus. The problem, as seen then, was supply and demand: “there are just too many cars, and not enough free land.” (The Tech, 1950) As early as 1957, parking was a known cost at MIT. There were suggestions by a special Institute committee to building parking lots under the tennis courts on Amherst Street, and to build platforms in the Main Lot. The committee’s report stated that

> “Underlying the entire parking problem at the Institute is the fact that parking facilities are a direct expense to the Institute, and that in the future these costs, both original and operating, are going to rise at a rapid rate. We strongly recommend that a policy of nominal charges for parking be adopted to help eliminate non-essential demand, and to help defray operating costs and/or build up capital toward the construction of new parking structures.”

They recommended an annual charge of $20 per year ($150 in current dollars), which, given the approximately 2,500 people who parked on campus at the time, would amount to $50,000 in revenue for the Institute. (The Tech, 1957) No action was taken on the recommendation.

In 1960, the construction of the parking lot next to Building 20 (in the center of campus) was completed for $2,500 per space in capital costs ($18,000 in current dollars). To meet that cost, a plan was floated to charge $30 per term for parking. The Institute Parking Committee, then in charge of the parking policy at the Institute, rejected this proposal. The same basic issue present today had already begun to emerge; parking areas were continually lost to the construction of new buildings on campus. Parking lots accounted for almost 16 acres of space on campus at that point, and were projected to account for up to 29 acres due to expansion and increased demand by 1975. (The Tech, 1960)

There was no charge for parking on campus until 1975, when the Academic Council approved an administrative fee of $5. As of 1990, MIT still did not charge anything other than a $10 administrative fee for parking. (Hester, 2004) At that time (as now), there were approximately 5,000 spaces for the then 16,000 person MIT community (there are now a little over 19,000 people on the main campus).

In the interim, the 1973 Federal Clean Air Act constrained the number of spaces that MIT could provide to no more than 36% of its commuting population. In 1973, Cambridge enacted a parking freeze (now replaced by a Transportation Demand Management program), which prohibited the creation of any new parking spaces, but grandfathered existing spaces from regulatory processes. During the 1980’s there was a lawsuit because the parking freeze had not been enforced. In 1992, Cambridge modified their zoning code (finally approved in 2000). Among the changes were a limit on the number of parking spaces that institutions could provide without being subject to further auto demand mitigation measures. At that moment MIT possessed an existing inventory of 4,814 spaces (3,711 allotted to commuter use). (Stone J. , 1990)

In 1993, MIT introduced parking access on the MIT ID card, in selected lots. This was the first step toward a more rigorous access system. This move is not yet complete, as all people who park on campus are still issued stickers for their cars. The system in place then, as now, records all entrances and exits. This access system allows MIT, if they so desire, to trace parking usage back to employees and students. (McDonald, 2002)

4.2.1 TRANSIT INTRODUCED

In 1996 MIT began its subsidized transit pass program; $10 in subsidy per month for all students and employees. This policy, “under consideration for the past 20 years” according to Lydia Snover, the Director of Institutional Research in the Provost’s Office, was approved by the Institute Parking and Transportation Committee. (Chuang, 1996) The intent of the program was to help the Institute "comply with the clean air standards, as an encouragement for the use of mass transit" according to then chair, Geoffrey Coram. It began as a trial to be re-evaluated after a number of years, as a way to encourage “the efficient use of resources.” The subsidy rate increased over the next decade, reaching a sliding scale up to 50% depending on the type of pass in the early 2000’s. The net benefit was capped so that the commuter rail subsidy was not 50%, but bus, subway, and combination passes (Combo and Combo+) reached the full 50% subsidy. In 2008, the Institute made the decision to increase the commuter rail subsidy to a full 50%. The resulting benefit was above that allowable by law to be pre-tax. This required MIT to place an imputed income charge on employees’ paychecks for the amount subsidized above the pre-tax limit. That charge has been rendered moot by the recent increase in allowable transportation fringes under the American Recovery and Reinvestment Act of 2009 (ARRA), to $230 for transit, matching the $230 allowable parking fringe.

MIT’s transit subsidy connotes an employer who both cares about the costs of their employees’ commute, and is environmentally friendly. Participation in the MBTA’s corporate program allows employees’ fare media to be automatically refilled each month, with no action required. Before the introduction of the CharlieCard in January 2007, employees had to pick up new monthly passes each month. This change has had both a positive and a negative effect on the perception of the benefit and its reflection on MIT as an employer. On the positive side, it associates MIT with increased ease and convenience. However, it reduces the ability for MIT to interact with the employee and remind them that MIT is subsidizing the cost of their travel.

Transit is a market with a single, established price. If people use the transit system, they see the full price posted at every entrance and exit. This reinforces the fact that they are getting a subsidized pass. What is less clear is whether they know that it is MIT that is providing this money directly out of General Institute Budget. Interactions during focus groups held in March 2008 lead this researcher to believe that there is a contingent of people who believe that MIT has negotiated a good price with the MBTA. To the extent that this perception exists, MIT does not share in the positive associations with the 50% transit subsidy they pay for.

4.2.2 PARKING FEES

In the late 90's, MIT instituted its first non-administrative fee for parking on campus, in part to allow for cost recovery of a benefit provided out of the General Institute Budget. By 2001, the cost of the parking permit at MIT was approximately $400 per year, and the Institute had begun their policy of increasing prices 11% per year to allow for increased cost recovery. With the exception of 2004, when the 11% charge was foregone because of a temporary freeze in salaries, that policy has continued to the present day. The parking charge for fiscal year 2008-09 was $786. When MIT instituted a parking charge it was not without hesitancy, nor was it a popular decision. Parking, while still highly subsidized, acquired an additional meaning: it was no longer a de facto benefit of employment. That the price then, as now, is significantly less than the cost of providing the benefit is mostly unknown to employees. (Institutional Research, Office of the Provost, MIT, 2008) Employees may expect that the price they pay for parking is the cost of providing parking. In their experience, employees do not pay to park at the mall, where they are going to spend money, but they do pay to park at work, where they are going to make money. For those people who were at MIT when parking was free, current parking charges signify how MIT has abrogated its responsibility to take care of its employees.

For new employees, the meaning tends to be the opposite. Despite the increased price (currently $65.50 monthly), parking at MIT is still inexpensive compared to other nearby institutions. At Harvard, parking costs $175 per month for reserved spaces, and $95 per month for unreserved spaces. At Boston University, parking costs $140 per month. (Harvard University Operations Services, 2009) At Massachusetts General Hospital (MGH) some spaces cost closer to $300 per month, more than 4 times the cost of parking at MIT. Within the Kendall Square area, private garages cost more than $250/month. This hidden MIT subsidy is not counted as compensation, and the visible payment is pre-tax. The price of parking was, and continues to be, a signal to new employees that MIT is willing to provide benefits to be an attractive place for employees to work.

As MIT has increased its parking charges it has continued to charge a flat monthly rate without regard to the position or tenure of the person parking, or the desirability of the parking location. Regardless of whether this is strictly true (de facto policy gives faculty higher priority for parking spaces closer to their offices), it is widely believed to be true. The lack of hierarchy in parking spaces is part of the self-image of MIT as an egalitarian meritocracy. In conversations with employees this positive association has arisen unprompted. This is a strict definition of equality as "the same for everyone." While being equal in amount, it is regressive in proportion. People with lower incomes pay proportionally more for their parking. As the price of parking has increased, this meaning becomes more visible. When parking is $100 per year, the cost is relatively insignificant whether you make

$20,000 or $200,000. When it is $700 per year, it is still insignificant at the upper range of the scale, but is no longer so insignificant at the lower end. On the other hand, the MIT subsidy of $1,800-2,300 per year is a more significant benefit proportionally for lower paid employees, but is not visible.

MIT also has an Occasional Parking program that permits employees to park up to 8 days per month for a low monthly charge ($4), and a highly subsidized daily rate ($4), with a rate after 8 days closer to full cost recovery ($10). It permits employees to participate in the transit subsidy and the Occasional Parking program concurrently, although at present the parking portion of the program is not paid for with pre-tax dollars. This program has been in place for approximately the last 10 years, but it has grown in use significantly in the last 5 years. In contrast to the Commuter Parking Permit, it does allow efficient flexibility in mode choices, although the incentives (pre-tax dollars and the policy limit on usage per month) mitigate these advantages somewhat. Without these more minor issues, it is a relatively good model of a policy that encourages greener commute mode choices.

The Occasional Parking program has meanings similar to both monthly parking and transit benefits. It sets a limit on the number of days the employee can use the scarce, polluting resource, and thus has an environmental gloss. However, the charge is low enough—cheaper than parking in many MBTA garages—that it acknowledges MIT's historical role in providing parking as a subsidized benefit. Despite the possibilities inherent in this program, the 8-day limit on parking thus far has painted the program as a complementary mode for those people who have committed to another primary mode. Furthermore, the program has suffered from a perception of unfairness by people who pay parking on a monthly basis, even though their parking is more highly subsidized. Because there is a history of lax enforcement in the outlying areas, there is the perception that many people take advantage of the program to both park all the time and avoid the charge. Thus, it runs afoul of the egalitarian ethos of parking at MIT. The program itself has much promise, but the difficulty of enforcement at ungated locations has, historically, undermined its meaning to non-participants.

In 2006, the newly hired President of MIT, Susan Hockfield, initiated the "Walk the Talk" program as part of MIT's new Energy Initiative on the MIT Campus. The intention of this program is to support programs on campus that reduce energy usage and mitigate the production of the pollutants that cause climate change. In her initial talk presenting the program President Hockfield signaled her intention to put MIT both on the forefront of energy related research, and at the vanguard of the sustainable campuses movement. (MIT Energy Initiative - Campus Energy Task Force, 2008)

The continued subsidies for parking take on another meaning in the context of the Walk the Talk initiative. Symbolically, the new Sloan building, celebrated as a green building, symbolically undermines the perception of MIT's commitment. The building includes 400 parking spaces, build at a cost of over $100,000 per space, which will exist for the life of the building. Each person parking at MIT produces carbon dioxide and other emissions in their commute. MIT parking subsidies increase the number of people who park at MIT. Free parking in the past encouraged employees to move to places that were more auto-dependent. This created an expectation that those policies would continue. Continuing those subsidies continues the incentives for people to live in areas that are less sustainable. Although commute trips represents only 25% of all VMT, the long-term effects of highly subsidized parking also make MIT partially responsible for the remaining 75%. Highly subsidized parking is the fly in the ointment of MIT's commitment to Walk the Talk.

MIT's transit subsidy has been recast as an example of MIT's commitment to "Walk the Talk." Both the subsidy that MIT provides to encourage its employees to switch modes from auto to transit, and its efforts to make that benefit user friendly and publicize the benefit, have an environmental gloss on it, both for existing and new employees, and for students.

4.3 Actors

The institutional actors, the goals of the institution vis-à-vis parking, and the motivations of those various actors to advance those goals, reveal that MIT does not speak or act with one voice. Understanding why decisions to change the structure of transportation benefits at MIT has moved thus far at such a gradual pace requires examining the motivations and roles of each of those voices. The goal is to provide insight into how to proceed on a path to success in the near future.

The MIT Parking Office, reporting to the Department of Facilities, runs MIT's transportation benefits program. The Department of Facilities is split into two portions, Operations & Security, and Campus Planning, Engineering and Construction. The heads of both of these sections report to the Executive Vice President, who in turn reports to the President of the Institute. The Executive Vice President is one of six direct reports to the President, and is responsible for all of the administrative and financial functions at MIT. As such, the EVP is responsible for MIT's annual $2.1b operating budget. MIT also own substantial real estate adjacent to campus through the MIT Corporation. Some of this real estate has been down-zoned by the City of Cambridge because of fear of the increased congestion associated with further development.

The Parking Office has an FY10 budget of $19 million dollars, and revenues of $6.8m. $3.6m of the Office's budget are so-called space charges, a cost to the parking office based on the value that parking spaces would have to the Institute, if they were used for another purpose. $4.8m are costs to the parking office for interest and depreciation on its existing structured parking garages, both under- and above-ground. The Parking Office also has an outlay of $2.5m for 928 leased parking spaces. Approximately 100 of these spaces are built into the leasing of office space, and thus are charged to the parking office, but are not under the manager's control. The Parking Office brings in revenue of $4m from employees, students, and visitors from parking fees. Furthermore, through its administration of the transit subsidy program, MIT pays the MBTA $4.8m per year, and takes in $2.4m from employees and students, $1.6m of which is from employees on a salary reducing pre-tax basis (thus saving employees approximately $500,000 on income taxes, and MIT approximately $110k on payroll taxes annually). The office spends $1.4m annually on its internal shuttle bus system and other commuter programs. There are also $2.5m in administrative and maintenance costs, including staff. Because capital planning is the responsibility of the EVP, the decision to build new parking spaces as part of any construction project is made two levels above the parking office.

While these charges, in one sense, all exist on the same budget, they have a number of sources of reimbursement from other budget entities in the Institute. The shortfall in operating and capital expenses for the approximately 4,000 parking spaces reserved for employees are paid for out of the Employee Benefits (EB) pool. The EB pool is split in its funding between overhead costs charged to research sponsors, and funding from the General Institute Budget (GIB). Also funded from the EB pool are MIT's transit subsidy, its membership in the Charles River TMA, its contributions to the EZ Ride shuttle and other commuting alternative programs, and part of its budget for running shuttles. Student parking and transit passes are charged directly against the General Institute Budget. Research sponsors do not pay any of the costs for graduate student benefits, but do pay the costs for employee benefits. In past years there have also been directly endowed gifts from donors to provide additional shuttle service, and funding for special projects.

Among other tasks, the parking office is responsible for disseminating information on the transportation benefits available at MIT to the students, faculty and staff of the Institute. The parking office administers an extensive website that provides the community with information about available commuting options. Most of the day-to-day contact with individual employees is delegated to department parking coordinators. The first parking permits at MIT were issued based on whether the car was "essential" to an employee's commute. The process has evolved so that each department is issued a certain number of spaces in specific lots based on the total number of employees in the department and their job classifications. A parking coordinator for each department determines the distribution of those spaces to their employees at their own discretion. Parking coordinators have various methods for distributing those spaces, usually based at least loosely on tenure, but often also based on "need," and in some cases based on a lottery system.

Parking coordinators vary in their depth of experience. Some have been in their positions for an extended period of time, whereas in other departments it is a sort of "initiation rite" for new administrative employees. These parking coordinators are also responsible for disseminating any announcements that come from the parking office—lot closings, snow emergencies, or changes in programs to students and staff— to their department. The parking office is directly responsible for all "exceptional" permits, including carpool permits, medical permits, etc. The parking office does not have direct control over the amount of information new employees are given about the benefits available to them. This responsibility is held within the human resources department.

Unlike the allocation of parking spaces, both employees and students are responsible for signing up for transit benefits directly, via the web site of the transportation and parking office. Recipients of the LinkPass, which is distributed on the MBTA's CharlieCard smart card, pick up their cards the first month they have signed up in one of two locations on campus, after which it is automatically refreshed on the first use of each month, unless they have cancelled their pass in the interim. Those people who resume after canceling their benefit must return to the office to pick up a new card. Employees and students who receive commuter rail passes must pick up their pass each month, as they are not yet available on CharlieCards. The main office where cards are disseminated is in the same location where students and employees receive their MIT ID cards. The ID cards control access to buildings, offices, athletic facilities, and most parking lots on campus, as well as serving as a repository of TechCash, a debit based system used in dining facilities throughout campus, and in nearby private establishments.

There is one other official decision making institution on campus, related to the administration of the transportation benefits programs. The Transportation and Parking Committee is composed of representatives from various administrative groups on campus, including one student representative. There are also *ex-oficio* members from various departments responsible for operations. It meets approximately 3 times per year. It can recommend changes in the transportation programs at MIT to the EVP's Office, but does not have official power to carry those changes out.

Additionally, there are a variety of advocates on the campus who have expertise in transportation matters. Among these are Nigel Wilson, a Professor in Civil Engineering, John Attanucci, a Research Associate in Civil Engineering, and Frederick Salvucci, a Senior Lecturer in Civil Engineering and former Secretary of Transportation of the Commonwealth of Massachusetts. There have also been a number of student advocates over the past 5 years, including Ursula Hester, who wrote a master's thesis on Universal Access passes in 2004, and members of a special studies course on sustainable transportation at MIT in 2007, among others.

4.4 CONSTRAINTS

The 4,814 spaces that MIT possessed before Cambridge's parking freeze are a "soft cap" on the total number of spaces MIT is allowed to provide to its students and employees. MIT can apply for additional parking spaces above that threshold. Additional spaces require a detailed Parking and Transportation Demand Management Plan, approved by the city. MIT views such a plan as a risk. The mitigation measures insisted on by the City may be in excess of that required by MIT to keep demand under the cap. MIT believes that the City could include "alternative transportation incentives that ... could place permanent financial obligations on the Institute." (McDonald, 2002)

There are exceptions to the cap. Until recently, the number of spaces that MIT leased was not counted against the cap of spaces managed by MIT. Thus MIT, at times over the last 15 years, has been higher than the 4,814 cap. These spaces are leased both to meet demand at MIT's offsite locations, and to replace parking lost by construction projects. In the last 18 months MIT has come to an agreement with the City of Cambridge to re-assess the actual number of spaces in use, and to include leased spaces within that determination of the cap. Only campus owned and controlled spaces are including; on-street parking on adjacent streets and Memorial Drive are not included within the cap.

Cambridge's incentives for parking are not one sided. In the early 2000's Cambridge changed their zoning code to permit parking underground as-of-right (without requiring a variance) without counting against the Floor Area Ratio (FAR) of the project as a whole. This helped encourage MIT to build a new underground parking garage as part of the construction of the Stata Center. (McDonald, 2002) Following this was the decision to replace the spaces displaced by the new Sloan School of Management with a new underground garage, to be completed in 2010. From an urban design point of view, this encourages MIT to use ground floor and higher space for active use, but this comes at the high cost of building underground. On the other hand, there is strong incentive to build in a significant amount of parking when a new building is constructed, because it will be impossible to add later.

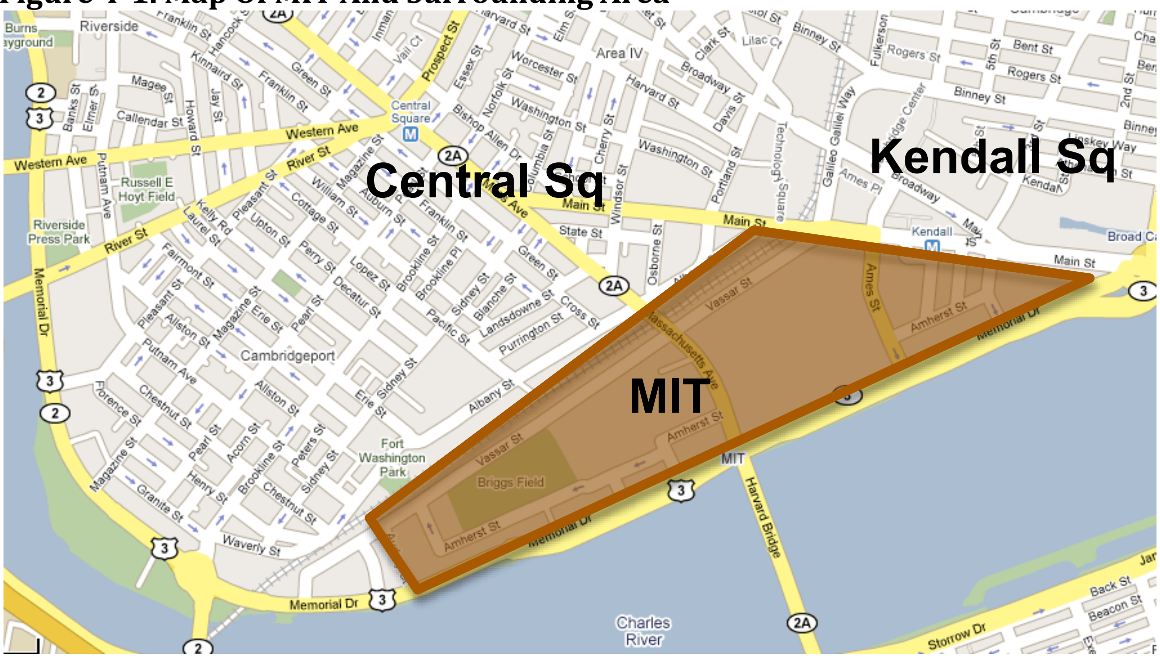
4.5 OUTSIDE CHANGES

In January of 2009, the MBTA introduced the CharlieCard, for use on its Subway and Bus routes, a SmartCard system that is refillable, and has multiple purses for different fare types and accounts on a single card. This has allowed MIT to cease its monthly distribution of Subway and Bus Passes. Because the MBTA plans to extend the use of these cards to its commuter rail routes, in the near future it will also allow MIT to stop distribution of commuter rail passes on a monthly basis. It also provided the potential to track usage on a per-card basis for the first time. Concurrent with the introduction of the CharlieCard, the MBTA also changed both its fares and its fare structure, allowing free transfers for CharlieCard holders between buses and subways for the first time, and eliminating the separate subway pass. This resulted in an increase in price for students and employees who formerly held a Subway only pass, but also an increase in the extent of the system that was available to them. This also decreased prices for those people who formerly held Combo and Combo+ passes (which allowed access to both buses and subways).

The physical environs of the campus have also undergone a significant transformation since MIT began allowing people to park on campus. Central Square, shown in relation to MIT in Figure 4-1, was redesigned and redeveloped to some extent in the last 20 years, the biotech sector has sprung up in the Kendall Square area, and Massachusetts Avenue by MIT has recently undergone a redesign to increase shade trees and pedestrian amenities, as well as a resurfacing. Various streets within the MIT campus have also undergone, or are currently undergoing, major changes to increase their pedestrian friendliness. Furthermore, MIT has begun and expanded its shuttle bus system on campus over the last 20 years.

MIT has made a commitment to improve its campus, and has demonstrated its willingness to work with the City of Cambridge to improve the surrounding area. The environment surrounding MIT is not the industrial wasteland it was 50, or even 15 years ago, thanks in large part to MIT's own efforts. These changes to the physical campus allow MIT to re-assess its policies on parking that were created when the destination of its employees trips was not as pedestrian friendly as it is now. The MBTA's new capabilities with its CharlieCard allow MIT to examine the subsidy program it has administered for the last 10+ years and assess whether it meets the Institute's current needs and goals.

Figure 4-1. Map Of MIT And Surrounding Area



4.6 Decision Point: Expanding Campus Facilities & Building Underground Garages

Who does the Institute perceives as its community? Is it the entire employee or student population, specific employees, or some other group? The decision to rebuild parking spaces to replace those lost to campus expansion exposes the conflict between the connotations of parking benefits. Space in the central areas of campus is in short supply. The current primary use of any space suitable for new construction is surface parking. When new construction begins, a temporary decrease in parking spaces available, which are highly managed, is mitigated by an increase in the number of spaces leased by MIT. MIT does not expect or plan for a decrease in demand simply because a new building goes up. Given that situation, MIT must then determine whether to rebuild (or increase) the number of parking spaces in the long term, after the construction period is over. This decision is commonly the question of whether to build an underground garage into the new building.

In the last 5 years, MIT has made the decision to replace the parking spaces lost during construction of the new Sloan School of Management with mostly underground spaces. Unlike leased parking, or surface spaces, underground parking is not easily replaced. It is a permanent addition to the building, which if unused, is essentially wasted space. Underground spaces are a decision that has long term implications for the meaning of parking at MIT. The cost of new parking outweighs both the average cost of parking on campus, and the cost of leased parking (by between $2,000 and $4,000 per space per year vs. leased parking). That is to say, at the marginal cost of constructing parking, the 11% annual increase would have to continue for a additional 12 to 19 years just to reach the same 72% subsidy level that it is now. Cost recovery and the decision to build new parking spaces are clearly not complementary policies. Assuming that the Institute has considered the implications of these calculations, they have either not considered the long-term implications, have come to the conclusion that 11% increases are sustainable in the long run, or have decided that cost recovery is not a valuable policy. This de facto policy creates a situation where there is no market price for parking at MIT. [3]

This decision is not strictly economically rational. MIT could pay people to park in existing leased spaces for less money. MIT has, in essence made a commitment to the existing number of parking spaces, and subsidies for those spaces, for the foreseeable future. In this decision MIT is asserting that the primary meaning of parking remains, that of "MIT will help you get to your job," in direct contravention of "MIT Walks the Talk on the environment." Because MIT increases the price of parking year over year at higher than the rate of inflation, they do not reap the benefit of this decision in more positive perception by employees. Inasmuch as the employees have gotten used to their new, temporary, parking spaces during the construction period, they may in fact even engender the opposite perception.

Would employees rather receive the $2,000-4,000 per year that parking costs to build on the margin in kind if and only if they park, or would they rather these dollars be used to advance the institute mission or increase their remuneration? Do employees prefer an implicit subsidy for an unsustainable mode of commuting? One could imagine a series of other policies that would provide the same benefit to employees, whether through direct payments, through housing allowances, or some other direct benefit to reduce commuting expenses. This policy might be more sustainable, have benefits that were more widespread, better attract new employees, and make existing employees happier. For example, for the $40m spent on the Sloan Garage, one could provide $200 in transportation subsidies to each and every employee every year for the next 40 years. In essence, the decision to build the Sloan Garage is the decision to take $200 out of the pocket of every employee,

[3] On the other hand, while parking is essentially free building mass because of Cambridge's Zoning Code, it might be put to other uses that do not need natural light, with Cambridge's blessing.

and concentrate the benefits in the 4% of the employee population who will make use of the garage.

Given this alternative, it becomes quite clear that the community beneficiary of the decision maker regarding the decision to build new parking is not the entire employee base. One could argue that the decision maker is captured by the people who have had parking in the past. The decision maker is captive to the meaning of parking, a meaning that was established when parking was a cost effective benefit, rather than one that sees a cost recovery of less than 15% on the margin. While this may be directly true, it is also not a complete answer. The decision to build new parking is actually twofold. When construction begins, the decision is to remove existing spaces on campus and replace them with off-campus leased spaces. The Manager of the Parking Office makes this decision. The second decision is to replace leased parking spaces with new, underground garage spaces. This decision is made by the EVP's Office, in association with campus planning.

In the case of the Sloan Garage, this implies that parking closer to the office locations of these 400 workers is valued at the difference in cost between leasing spaces and building new garages. The price of one space of leased parking is approximately $3,000 per year, rising at about 5% annually. The price of a new garage is at least $5,000 per year, and likely closer to $7,000, with an additional $400-500 in operations cost per year per space. Only the operations cost rises at about 5% per year. Using a net present value analysis, over a 40-year period (the projected depreciation for all garages on campus), with a parking space that costs $125,000 to construct, provides the implicit value of the closer space. The value of the time savings and convenience must be worth the equivalent of a one-time $20,000 bonus to the individual using the space, in order for the Institute to break even.

This analysis further assumes that there is no higher and better use to the Institute for that space than parking (that is, that labs, classroom library space, etc. has less value to the Institute). If this were to be the case, then there would be no Institute space charge allocated to parking. Current space charges on the parking budget are valued at approximately half of the debt service costs. This is equivalent to $60,000 in opportunity costs per space.

Thus far this Chapter has assumed a rather static campus setting, with parking replacing existing spaces, but no new spaces being added. This is in part due to Cambridge regulation; new spaces are hard to add. They are not impossible to add. In the past year, MIT has temporarily abandoned its expansion programs, but one assumes that this is not a permanent decision. Prior to the current economic crisis, MIT had plans to expand its employee base by approximately 1% per year for the foreseeable future. It has acquired properties throughout the adjacent Cambridgeport neighborhood commensurate with that desire. This begs the question of how MIT planned or plans to both comply with City and Federal mandates, while containing costs. It is likely that the pressures of growth will reemerge based on past plans, the increase in federal money for research that is a result of ARRA, and President Obama's increased emphasis on funding scientific research. The EVP's Office at MIT has previously stated that it sees the number of parking spaces it has within the Cambridge parking freeze as an asset. Given that parking spaces are an asset, the EVP's Office has pursued a certain set of policies that include maximizing the use of that asset. Assuming expansion, there may well be demand in excess of that cap. If this is the case, maximizing the use of an asset is no longer the operative policy.

In this setting, assuming that Cambridge will continue to enforce a de facto parking freeze, there will an increased reliance on reducing parking demand. Since traffic congestion has become more severe as Kendall Square has revitalized, Cambridge policy is likely to continue, or become more strict. Demand reductions will need to come from both from existing and new employees in order to avoid exacerbating congestion. Even with these reductions in mind, MIT is likely to construct new parking spaces to replace those on which new buildings are built. Given the expense of this endeavor, if MIT continues to perpetually increase prices for parking above the rate of inflation seem likely, creating ongoing increasing tension with the MIT egalitarian ethos. The operative question will be then, as it is now, how does MIT increase these prices? Does the Institute continue increasing prices across the board? Or, does it allow employees more gradual optional mitigation, such as through daily parking fees, differential pricing based on the convenience of the parking space, or more attractive transit subsidies?

The disconnect with the goal of Walking the Talk and the continued act of subsidizing parking at higher rate than transit is also evident. The transit subsidy, including Commuter Rail, averages less than $45 per month. On the other hand, the subsidy for parking on an average cost basis is approximately $160 per month, and higher on a marginal cost basis for both leased or constructed parking. This is both a higher subsidy in nominal dollars, and in percentage terms. Transit is subsidized at 50%, whereas parking is subsidized at 72% on average. These differing levels of subsidy change the attributes of the choice for employees, and encourage fewer people to "Walk the Talk" than otherwise would.

4.7 Decision Point: Pay Freeze And The Increase In Parking Prices

In the course of the last year, as the economy has weakened, MIT has seen its endowment fall significantly. This has prompted across the board budget cuts of "$100-150 million (i.e., 10- 15% of the GIB) over the next two to three years" (Stone T. , 2008), pay freezes for all employees making over $75,000 per years, and minimal pay raises for all other employees. In this environment, the transportation benefits programs, and especially the cost of parking, both to employees and to the Institution, potentially becomes a battleground.

Parking costs represents 1.6% of GIB expenses, approximately 50% of which is charged via overhead to research sponsors. The revenue from parking charges and the transit program represents approximately 0.5% of GIB revenue. The 10-15% GIB decrease over the next two years means a reduction of $1.6-2.4m to the Parking

Office budget if those space charges and items that are not controllable by the parking office are included. If they are not included, it requires a reduction in the budget of between $800k and $1.2m. If one includes the total cost to the Institute of the transportation subsidy programs, including revenue cost recovery, this would require a decrease in the budget of $1-1.5m. The extent of the impacts of the 10-15% reduction are thus unclear, and may have significantly differently effects depending on which part of the budgets the cuts are applied to.

More generally, if the Institute sees the transportation budget from the perspective of a cost center, there is an incentive to save money. This goal is slightly different than a for-profit corporation's incentive to reduce costs. To some extent, any money-losing portion of the Institute is self-mitigating, inasmuch as it is funded by administrative overhead built into research contracts. This might give the Institute less incentive to control costs on employee benefits than it would have if money saved from parking could be spent on mission-enhancing endeavors. On the other hand, one could consider the administrative costs of the research contracts as built in revenue, facing a practical cap, and subject to federal audit, rather than the line item approach that the previous analysis implicitly assumes. If this is the case, any cost recovery from the transportation subsidy programs results in an extra pot of dollars that can be spent on other overhead budget item. Other items, such as more staff, increased absorption of the rising costs of healthcare and other so-called fringe benefit programs might better advance the mission of the Institute.

One suspects that this second type of analysis is closer to the fashion in which the Institute analyzes the need for cost recovery. This suspicion is based on the policy of increasing parking prices at 11% annually, significantly higher than the rate of inflation, over the entire last decade. The impetus for this decision was not a measure to decrease the demand for parking at MIT, but instead because cost recovery for parking was less than that for other benefits such as healthcare. (Personal Communication with Parking & Transportation Committee Members, 2008) The Transportation & Parking Committee has not seen fit to cease this policy over the last decade, and the EVP's office has agreed to implement the policy each year, with one exception. That 11% increase per year has had a significant effect on the degree to which the parking and transportation budget recovers the imputed operating costs, and the capital costs as manifested in the space charges and the interest and depreciation costs of the garages. At current parking prices, an 11% increase brings in approximately $300k of revenue annually. Assuming no new construction of parking facilities or other new costs, this would mean that the parking subsidy decreases by approximately 3% per year for the foreseeable future, from the current $1800+ annually.

The 11% annual increase represents an additional cost of approximately $86 per year for employees, many of whom are seeing their salary increase by less than $700, and in many cases not at all. The economic climate, which caused the Institute Budget to be cut, has also affected the values of people's housing and other investments. Freezing or mitigating the increase in parking prices is an important choice for MIT, given their historical preference to provide competitive benefits packages for new and existing employees, and their professed desire to Walk the Talk. The meanings of the parking benefit are now in direct conflict with each other. Maintaining the status quo requires choosing one of the meanings as more important. However, this need not be a win-lose solution for the Institute.

A reduction in the budget of the parking office means pain spread across the Institute's students and staff. If one were to spread the pain for an equal dollar amount among all people receiving a transportation benefit from MIT, an additional $1m in revenue would mean an increase in costs of about 30% for both parking and transit. Given that the transit measures are part of the SOV mitigation measures agreed to with the City of Cambridge, a reduction in these benefits is unlikely at this juncture, and would threaten the Walk the Talk objective. If the reduction is achieved via parking prices it requires a one-time increase of approximately 40% in the cost of parking, which would generate tension with MIT's egalitarian and employee friendly objectives. It could also be achieved by eliminating half of MIT's leased spaces, as long as no money is spent on mitigation measures (that is, 500 fewer people are allowed to park at MIT). Alternatively, more than half of MIT's leased spaces could be eliminated to provide funds for increased transit subsidies. This would aim to resolve the conflict between environmental and benefits goals, and restore equity to the transportation benefits offered.

Increasing parking prices is less painful to employees than commensurate reductions in salaries (or reductions in expected salary increases), because of the tax advantaged nature of the transportation benefits programs. Conversely, increasing the subsidy for other transportation benefits is less costly to MIT than commensurate salary increases. Since parking has a significantly higher cost per person to the Institute in subsidy cost than transit and other commute alternatives, providing transit subsidies has a compound benefit. Not only is it cheaper than commensurate direct monetary compensation on an after-tax basis, it also has the possibility of facilitating and mitigating the elimination of costly leased parking by reducing demand for parking.

If the decision is whether to forego the 11% parking increase temporarily, it can be framed in terms of alternate ways to raise the equivalent money. For example, reducing the transit subsidy for employees by $300,000 is equivalent to an $82 per year decrease for each employee who has a subsidized transit pass. Equivalently, MIT could decide to remove $80 from the raises for those people who are still receiving raises in the fiscal year. For a 1% raise, this represents 10-20% of the total raise, depending on salary. Given the past decisions to build parking at high marginal costs, is it more equitable to distribute these costs across the entire campus, or to operate on a user pays principle?

Assuming that the $300k to be raised from parking revenue is inviolable, the question becomes are across-the-board increases the most effective manner in which to raise that revenue? On the one hand, there is the meritocratic egalitarianism ethos that is prevalent at MIT. Across-the-board increases seem equitable because they do not privilege any particular group. However, across the board increases are regressive within the group of people who use parking at MIT. Charging for parking based on income has been proposed in past employee forums. Neither the EVP's Office nor the Transportation & Parking Committee has endorsed these proposals. Some parking coordinators seem to have struck a middle ground in regulating this policy, by allowing only those employees who have demonstrated need to have commuter parking permits. This policy is quite variable throughout the university.

If MIT simply increases the transit subsidy, this seems as if it would be consistent with Walking the Talk. However, it would not fully mitigate the impacts of the behavioral change required of those employees whose leased parking spaces were eliminated in order to meet the additional $300k in additional revenue required. Across-the-board parking price increases do not allow mitigation by driving less. Instead, mitigation can be achieved in two ways: (1) Complete mode switch; (2) Switching to an Occasional Parking Permit. The switch to Occasional Parking may require changing the area in which the employee parks, and driving significantly less (fewer than 8 days per month). The Institute is therefore pursuing an all or nothing policy in terms of employees' happiness. Employees can mitigate the price increase through major lifestyle changes, or they can simply accept that the prices will continue to increase.

Complementary to daily parking, if parking prices are raised, users can switch to transit. For most employees this is a less expensive option. With prices stable for transit, the increase in parking prices allows employees to mitigate the increase by not driving. A decrease in salary or an increase in transit prices does not facilitate employee mitigation measures by changing their behavior to a less costly form of transportation in the same manner.

Increasing transit subsidies in a strained economic climate may both save the University money, and allow MIT to have a more attractive benefits package than competing Universities, while seeming and actually being environmentally progressive. With the economic situation increasingly driving the retrenchment of benefits programs among other employers, the "green aura" may be a competitive advantage for the academic and research staff that MIT must continue to attract to advance its mission. Chapter 7 investigates methods of targeting the benefit to those people who switch modes, and attracting full time parkers with free or low cost transit passes.

4.8 Decision Point: Energy Initiative

More parking spaces means more people parking on campus. You do not need a complicated formula to come to this conclusion. Parking garages last a long time. They are a commitment to keep those parking spaces, which have no value if they are not used, of at least 40 years (the period over which the Institute has chosen to depreciate them). This section attempts to demonstrate that the Institute's lack of movement on transportation initiatives as part of Walk the Talk is driven by a conception that that transportation is not a significant part of campus energy usage or emissions, and that public transit is not significantly more efficient than SOV travel.

The Energy Initiative cites a graduate thesis written by Tiffany Groode, MS in Mechanical Engineering, 2004 as the authoritative document for the base energy usage and CO_2 emissions on campus. (Groode, 2004) But Groode's primary focus in here thesis was on building efficiency, not transportation. Her brief analysis of emissions from transportation was intended to justify her focus on buildings. Her analysis of transportation focuses only on CO_2 emissions during the 4,000 miles of commute trips per person. She uses a calculation based on US averages for emissions from bus and subway commuting.

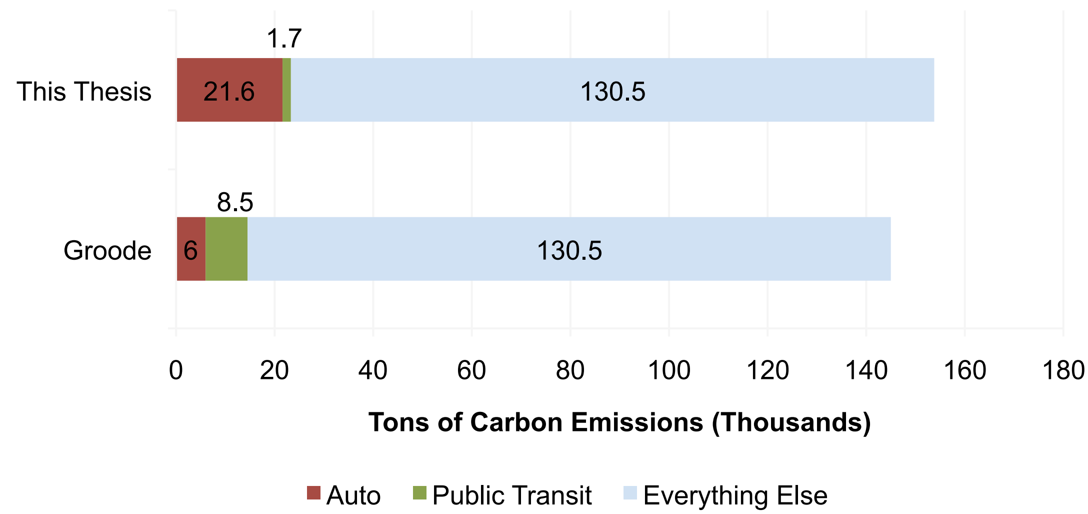
This calculation overestimates the contribution of public transit to emissions in two ways. First of all, bus occupancy in the US as a whole is significantly lower than that in the Boston. Higher occupancy equals fewer emissions per transit rider. With automobiles the marginal and average cost of an SOV commuter are equal absent congestion effects. An analysis that recognizes that the MBTA does not tend to add service in response to increased ridership would show that the marginal cost of an additional transit rider is closer to zero. Groode's calculations use 2002 commuting numbers of 4,800 employees and students on campus commuting by public transportation, and 3,700 commuting via auto. Her findings show that emissions from public transit are significantly higher than from auto commuting (6,000 tons from auto commuting vs. 8,500 to 10,000 tons from commuting on public transportation). Another likely source of error in this estimate is her usage of the same average trip length for auto commutes, transit commutes, and bus commutes. Additionally, the commute is almost always a "cold start," with higher emissions. Neither does she include the added fuel consumed and emissions of localized congestion near MIT due to auto usage.

Moreover, any calculation should consider the potential emissions for all trips rather than only the emissions from the commute trip. Calculating emissions and energy usage from transportation should take into consideration the lifestyle of the person, of which driving to MIT is merely a portion. The baseline against which to measure change should not include the emissions reductions made by MIT given their current policies. The potential to commute by automobile is (generally) held by each person at MIT. It is only MIT's current policies that prevent this from occurring.

The preceding observations indicate that Groode has both underestimated auto energy emissions and overestimated transit emissions (and by inference energy usage) due to transportation. This does not impact Groode's analysis of building emissions, and thus does not impact the value of her thesis. However, MIT's use of the document as the authoritative source for emissions on campus, (MIT Energy Initiative - Campus Energy Task Force, 2008) also utilizes her analysis of transportation .The implication is that the Institute bases policy decisions on a world where transportation represents less than 10% of all emissions, and public transit is not a particularly effective emissions reduction mechanism. Instead, the Walk the Talk committee focuses on what has already "been accomplished."

In accounting for emissions, the commute trip is a significant factor in residential location and car ownership. Each of these decisions has a large effect on total VMT via the automobile, and total emissions. Given that the commute trip typically represents about 25% of total VMT, total emissions due to MIT's policies is up to 300% higher for auto commuters (if the commute trip is determinative of a person's entire emissions from transportation). Figure 4-2 compares Groode's methodology to one that uses marginal calculations for emissions from public transit, and includes the full emissions from the commuter's trips, rather than only their journey to work VMT. Using marginal calculations, emissions are up to 100% lower for commuting by alternative modes, including public transit, walking, and biking.

Figure 4-2. Comparison Of Groode's Estimates Of Transportation Emissions At MIT To This Research



Source: (Groode, 2004)

4.9 DECISION POINT: RECENT TRANSPORTATION SUBSIDY CHANGES

In the last year, the Institute has expanded its experimentation with policies to reduce transportation energy usage and emissions, with an admitted focus on "those commuters who have the longest commute." (MIT Energy Initiative - Campus Energy Task Force, 2008) There have been two policy changes. (1) In October 2008 the Institute officially increased their subsidy for transit passes to 50% across the board. Prior to that point, the transit subsidy was capped, so that for the farthest outreaches of the Commuter Rail system, the MIT subsidy was approximately 30%. (2) The Institute offered a single month's free transit pass to any commuter with a full-time parking permit in September of 2008.

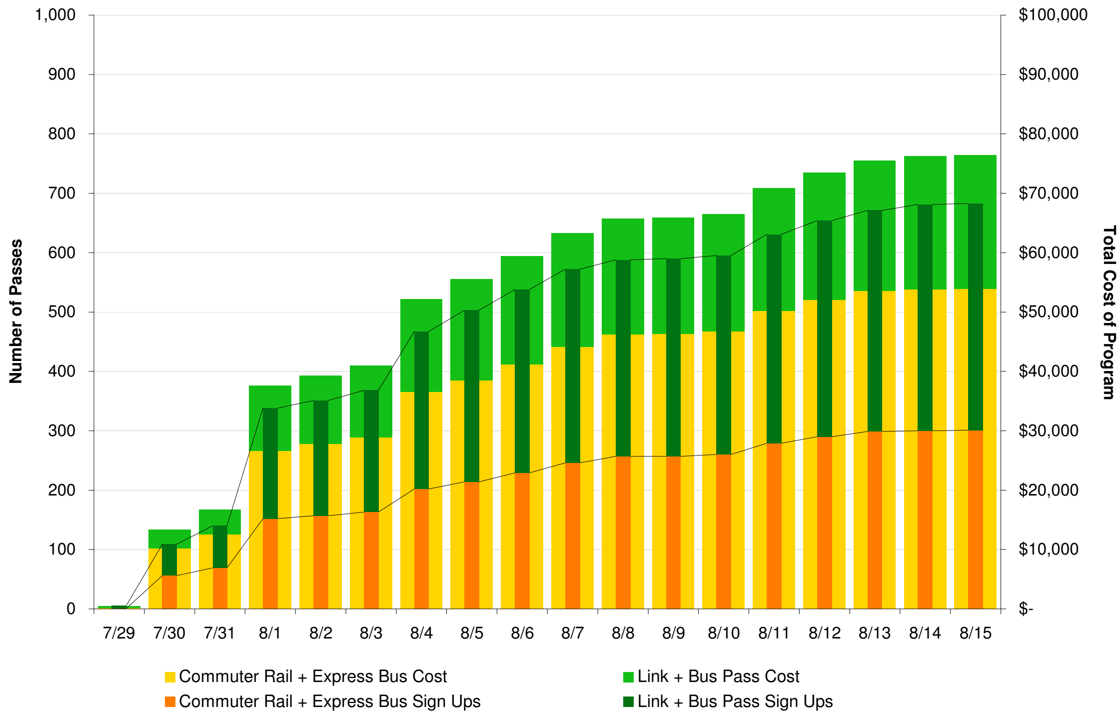
Neither of these policies appears to be a particularly cost-effective manner to decrease SOV usage. Given common elasticity measures (price sensitivity of -0.3) for demand responsiveness to fare changes for public transit, the price changes for the commuter rail subsidy would result in an 8% increase in commuter rail usage. This increase costs $17,000 per month; an average cost per new rider per year of $4,400. Given the total cost to MIT of a Zone 8 commuter rail pass (the outermost zone) is $3,000 per year, this was clearly not a program designed to attract new riders, but instead to compensate (or retain) existing riders. On the other hand, it is without question a greener and more equitable policy than using those same dollars to build or lease parking spaces.

The above results point to one of the issues with increasing transit subsidies for monthly passes, without using the innovative techniques described in Chapter 3. While any increase in subsidies would be tax deductible, these increases are likely to see decreasing marginal returns compared to earlier increases, and to be quite costly. The base of people who take transit is quite high, so any increase in transit subsidies also compensates those riders who already use transit. Assuming a demand elasticity with respect to price of -0.3, the implication is that an increase of subsidy of 10% of the unsubsidized cost of a LinkPass, would result in an increase in riders of 6%, but would need to be paid to both existing and new riders. The cost of each net new rider would thus be 17.7 times the cost of a LinkPass. While this thesis makes the case that this would restore some measure of equity to transportation benefits, it is not the only manner by which equity can be restored. Universal Access passes can reduce costs for both existing transit riders and new riders, and achieve the environmental outcomes associated with Walk the Talk.

The second major trial that the Institute undertook was the September distribution of free passes. Approximately 25% of all Commuter Parking Permit holders requested a pass from this experiment, and it resulted in fewer than 70 people switching to transit at the end of the free period. As shown in Figure 4-3, the result was an average cost of over $1,000 per person no longer driving. From a cost recovery perspective, this was a successful program, assuming it did not increase occasional usage of parking significantly. The Institute can now give up a leased parking space that costs a net of $2,250 annually for each person who converted to transit. From an emissions perspective, it may not be the most cost-effective mitigation measure as compared to increased subsidies for transit, but it is clearly cost-effective overall for the Institute if it facilitates eliminating leased parking.

It is evident MIT has tried very few new policies to Walk the Talk in the transportation sector since the Energy Task Force was initiated. Those policies that were pursued were not particularly cost effective by design. Either (1) the administration saw those policies as the most cost effective measures they could take, or (2) they are willing to partake in measures that are not cost-effective, so long as they are temporary or remunerate a group whose subsidy is viewed as inequitable. Given discussions with the Institute around the time both measures were begun, it seems likely that the second explanation is closer to the truth. If this is the Institute's policy, then any further changes will need to meet one or more of the apparent criteria: temporary, cost-effective, or correcting a previous inequity.

Figure 4-3. Results Of September Free Pass Initiative



4.10 CONCLUSIONS

It is in this context of the preceding decisions that any further decisions to modify the transportation subsidies on campus will be made. The difficulty lies in mediating between intentions, perception of intentions, outcomes, and perceptions of outcomes. The meaning of parking is essentially a series of perceptions of intentions, not necessarily of outcomes. Outcomes are important, but they are mediated by existing perceptions of the motivations of the actors. A respected "non-partisan" figure on campus arguing for increasing parking prices is more likely to be taken as having good intentions than a budget administrator whose primary responsibility is reducing the budget. Both the medium and the message are important. The outcome, and the perception of that outcome, is affected by how issues are framed. That framing is, in turn, a choice among the existing meanings of transportation benefits programs to both the administrators of those programs—the EVP's office, the Transportation and Parking Committee, the parking coordinators—and the employee and student population.

Recall that 50 years ago the Institute made the decision not to pursue a policy of full cost recovery for the construction of parking facilities through employee charges, despite an Institute Committee recommendation to the contrary. It would be hard to conclude that, for all the changes that have taken place, this policy has changed.

5 Mobility Pass at MIT

The previous chapter reviewed the history and role of parking and transit subsidies at MIT, and how they have been affected by and interact with the various actors who make policy. This chapter begins by reviewing the motivations for changing the current transportation subsidy regime at MIT, from the perspective of the Institute, faculty, staff, and students, and the MBTA, as well as the City of Cambridge. It then reviews the history of the so-called Mobility Pass program, including how the program has been presented to policy makers at MIT, and how it may fit into the current economic situation facing the Institute. It concludes by detailing the policy options that are analyzed in depth for costs and benefits later in this thesis. The analysis in this chapter focuses on how decision makers perceive those benefits.

5.1 The Opportunity

The increasing prevalence of SmartCards as fare media allows transit agencies to make a fundamental change to the way they administer Universal Access programs. For existing Universal Access passes in practice employers still pay a set price per transit pass. This price is just lower than it would otherwise be. In this new model (the Mobility Pass), rather than paying a fixed price per employee or per card, the employer agrees to pay for the usage of its employees, as tracked by the SmartCard. In essence, the employer is the guarantor of fare revenue. Negotiated prices are not needed. There is no risk to the transit agency of use of passes by non-employees, since the transit agency gets the per-ride cost whoever uses it. The risk, inasmuch as it exists, is borne by the employer. The transit agency is guaranteed full fare for each ride. If ridership increases, the transit agency gets the revenue immediately. Payments are not lagged, nor are they discounted. The program is by definition revenue neutral to the transit agency for each employee, each employer, and for the program as a whole.

The employer can offer access to its employees (universally or a subset) on a zero-marginal cost basis. That access can follow the employer's current subsidy regime, be fully subsidized, or discriminate based on expected usage (e.g. charge people who park on a daily basis less than those who take transit). The employer has better information by which to charge differential prices based on expected usage than the transit agency, removing some of the employee concern with a paying for a program that they perceive not to benefit them. In this model employers are able to provide low-cost incentives for drivers to trial transit and for those who occasionally take transit to take it more often. Twenty people exchanging their cars for trains or buses every fifth day has the same aggregate effect as four people taking transit every day.

5.2 Motivations

5.2.1 MIT

As detailed previously, although MIT has been increasing parking prices by 11% per year, the cost of providing that parking has been increasing at a greater rate. Any new building construction at MIT is scheduled to take place on the only existing unbuilt areas on the campus, surface parking. Furthermore, MIT has a significant amount of parking at commercial garages on annual leases, which can be terminated. Thus, even in a contracting economic climate, there is an economic incentive for the Institute to reduce SOV commuting.

At the same time, the academic market remains competitive in attracting talent at all levels. None of MIT's local competitors price parking at market rates, but all of them have more expensive parking than MIT. On the other hand, if you are recruiting a researcher from California, they may not expect to pay for parking at all. Competition thus takes place on the amount, kind, and price of parking, and the amount of the transit subsidy. MIT also has a soft cap on the number of parking spaces it can provide due to the Cambridge parking freeze. This means that the existing number of parking spaces needs to be well managed and fully utilized to provide the maximum benefit in attracting and retaining employees. Convenient visitor parking is a significant unmet need; there is only a single small lot which does not require previous arrangements to park in adjacent to campus. Furthermore, "green" measures by the Institute are an attractor for employees, all else being equal. People have a desire for their Institutes values to align with their own.

The "low hanging fruit" of mitigation measures, including extensive transit subsidies, have already been picked. Those people who can be attracted to commute full time—or nearly full time—by transit have already been converted, with the help of economic incentives. Increasing transit subsidies across the board is thus an expensive measure that is unlikely to reap the same rewards it has in the past.

Lastly, MIT has a responsibility to educate its students. A not insignificant portion of the draw of MIT is the urban setting of Boston. MIT already limits the amount of parking available to its students on campus because of lack of supply. Zero marginal cost transit would encourage students to make use of the Boston area as an extension of their academic experience at MIT. Campus shuttle systems are necessary means of providing transportation subsidies to students for travel within campus. These shuttles do not extend to other institutions in the area, at which students can cross-register. Thus, there is an academic and more broadly defined educational objective for MIT to encourage students to use public transit.

5.2.2 Faculty, Staff, and Students

Existing faculty and staff have an interest in not seeing the cost of their commute increase. This can be defined in two ways: (1) As a desire to maintain the same behavior, at the same cost. (2) As a desire to maintain the same equivalent disutility (or reduce it). Utilizing the second definition, this might include switching modes based on differing subsidy levels, or mitigating costs or time budgets by switching modes occasionally if the incentives are correct and this behavior is "permitted" by MIT. This coincides with a desire for (1) MIT to reward them for more environmentally friendly commuting behavior, and (2) to increase total mobility, based on variable commuting needs outside of the Institute's controls, but unique to each household.

Students on campus have significantly simpler motivations. Among other things, they want to avoid any charges that they might be responsible for, such as student fees, while maximizing the amount of discretionary money they can spend. Off-campus students have motivations somewhere between employees and on-campus students, with the exception that few of them have cars. Thus their mobility is largely based on access to transit and non-motorized transportation.

5.2.3 MBTA

Like the other transit agencies in Chapter 3, the MBTA's main goal in any program is to increase ridership, and at the very least to maintain existing revenues. Its managers have expressed a desire to increase off-peak ridership, since this does not require increasing capital or operations expenses. This leads to an interest in increasing ridership not just for employees, but for students, who tend to travel disproportionately during off-peak periods. These goals are in the context of a very successful corporate program to sell monthly passes, which is often already subsidized by employers. These subsidies increase ridership and revenue versus a no subsidy situation, at no cost to the MBTA. Thus the MBTA has the desire to increase ridership, while maintaining its existing, and profitable, corporate pass programs. Furthermore, the MBTA has expressed a desire to retain a perception of fairness in their fare policy. That is, the MBTA does not want the bad publicity associated with "a good deal" for corporate customers that is not available to other riders. They also want to make sure that any trial program creates the proper climate for an expansion of transit benefits offered by employers in the region.

5.2.4 City of Cambridge

The City of Cambridge is significant to any program. Their interest is in congestion and emissions reduction, both for quality of life issues and attainment of clean air standards. This is combined with a desire to increase their tax base, especially with respect to non-residential property. That is, they want growth, but they want the transportation and livability effects of that growth to be mitigated. They require mitigation of any increase in net travel demand for employers in excess of their allowed parking spaces, via such mechanisms as street improvements, transit subsidies, contributions to local shuttle services and Transportation Management Associations, etc. Cambridge also provides incentives for construction of new parking underground via zoning regulations that do not count underground parking against Floor Area Ratio (FAR) limits, which is consistent with their urban design objectives and indirectly supports their congestion mitigation goals by making parking expensive for the developer, and presumably for therefore inhibits the amount of parking built.

5.3 Mobility Pass History

It is in this context that efforts to modify transportation subsidies at MIT have been made. As established in Chapters 3, Universal Access passes are not a new concept.

In these programs the entire population of a defined group is given a transit pass, with a single entity taking the obligation to pay for the total usage of those passes. This spreads the cost of passes between those who use them, and those who do not, and thus reduces the cost significantly per transit rider, while providing unlimited, zero marginal cost access to the transit system to the entire population.

5.3.1 HESTER'S THESIS

At MIT, the idea seems first to have been broached by Ursula Hester, MCP, Department of Urban Studies and Planning, 2004, and Fred Salvucci, her thesis advisor. Hester analyzed the total transit outlay for MIT and Harvard, and estimated the cost of a Universal Access pass for all students and faculty. Hester lacked any real data on transit usage by non-passholders, and thus her cost calculations are somewhat underestimated. She estimated a $10 charge per month for students for a Universal Access Pass, and slightly higher charges for employees and commuter rail users, depending on how the cost was spread out amongst the group. (Hester, 2004)

An article in the MIT Tech referenced the thesis, with the headline that it would mean "mandatory" passes for students and employees. (Cao, 2005) It was also discussed at a meeting of the Transportation and Parking Committee. Hester completed her thesis and graduated, and the program was not pursued by the MBTA. On the student side there seems to have been some concern that it would mean an additional student fee. In almost all of the Universities that have implemented an Unlimited Access program, the students have voted to impose the fee. However, there is a particular sensitivity toward fees at MIT. More than 60% of the student body is made up of graduate students, most of whom are supported by Fellowships, Research Assistantships or Teaching Assistantships. These students, and undergraduates with financial aid, have all of their expenses covered, with the exception of fees. Their low baseline costs mean that any student fee has a perception of high marginal cost, relative to their current out-of-pocket expenses. The thesis did not detail how one imposes a mandatory charge on employees.

Hester also proposed that this card be integrated into the MIT ID. This proposal occurred when the changeover to the CharlieCard, which would allow such a program to proceed, was planned but not yet in place. This feature seems to have been the impetus for MBTA's decision to delay consideration of the program; they had no manner in which to track usage by the students and employees at MIT, and thus any program would have been dependent on estimates of usage.

The key insight in Hester's thesis was to link the proposal to a decreased rate of parking usage, which would lead to cost savings from foregoing future construction and current parking leases. The dollar value of this benefit was not estimated. This argument seems not to have been a breakthrough moment in publicity at the University. It was not mentioned in any of the press on the thesis, nor on the subsequent discussion on campus mailing lists. Thus, it is hard to assess the response of the Institute. Hester's thesis did call into question the cost effectiveness of the decisions to build new parking, but again, this seems not to have entered the public discussion.

On the other hand, the "mandatory" nature of the proposal had a rather negative reaction from the community. The public debate did not reach the point where widespread discussion of the program and education about its benefits was possible, so the reaction can only be assessed at a "gut" level. From this it seems that the proposal ran up against the concept of what a benefit entails in a university setting. That is, because it was not an optional program, it was seen as more akin to a tax than a benefit. It might provide necessary service in an efficient way, but it entailed some people winning and others losing. On the merits, all benefits policies involve some people gaining at the expense of others, since employee benefits all come out of the same, limited pool. The issue here was that the concept of shared cost was transparent, and the reluctance of the MBTA to proceed made it impossible to have the kind of discussion that has led to student support for Universal Pass programs on other campuses.

5.3.2 A Sustainable Transportation Plan for MIT

In the Spring of 2007, the Universal Access pass was revived during a special studies class, led by John Attanucci and Fred Salvucci from Civil and Environmental Engineering, and Larry Brutti, the head of the Parking and Transportation Office. The class, in which the author was a participant, was entitled "A Sustainable Transportation Plan for MIT." After extensive research, the class proposed three options for what they called a Mobility Pass that combined the parking and transit programs into a single transportation program. In the first option, a Universal Access pass would be mandatory, at a cost to all students and employees of $180 per year. In the second and third programs, pricing for lots would be on a daily basis, with tiered pricing based on convenience and demand. The two programs were differentiated by the spread of proposed parking costs; the tiers were set at $2, $4 and $6 per day for one, and $2, $6, and $10 for the other. The Universal Access component for these programs was not mandatory. However, it was bundled with the right to park on campus to guarantee participation by all current parkers. This was seen as a way to avoid the issue of mandating employee contribution to the program, while still retaining the majority of students and employees on campus with the program.

The class prepared a final presentation and report. That Spring, their plan was presented to the Parking and Transportation Committee. Working with Mr. Brutti and the Committee, the plan was revised, the marginal pricing removed (it was perceived as "too much, too soon"), and the system of allocating spaces to employees through parking coordinators kept. During this time, there were also meetings taking place with various campus deans, in order to ascertain support for the program and investigate implementation details. There was tentative support among all parties for a program that provided students with Universal Access.

In work that took place over the course of the next 9 months, meetings proceeded with the card office and members of the campus planning staff, among others, and the original proposal was revised. A number of additions were made in the interim, most notably that no person would be required to pay more than they were currently paying, with the year-over-year increase capped at the 11% annual increase in parking charges. Additionally, John McDonald, head of MIT's Card Office, had 2 test cards with the MBTA MyFare chip embedded in the MIT ID card manufactured. These chips were tested over a period of approximately 1 month, and functioned as expected. The Parking and Transportation Committee endorsed the revised proposal, and meetings with representatives of the EVP's office began.

The proposal made by the CEE special studies class built upon the framework of the Hester thesis. It began to consider in a more measured fashion both the long term cost implications of mode switch from SOV to transit for MIT, and the environmental impacts of the change. Because the class was the result of student involvement in the MIT Generator group, an offshoot of the Walk the Talk Energy Initiative, it was explicitly framed in terms of reducing emissions and energy use for transportation, predicting emissions 10 years out for the Mobility Pass. Based on the feedback during both the class presentation, and the subsequent presentation to the Transportation and Parking Committee, environmental consequences were seen as a prime driver for moving the proposal forward through the Institute.

Another part of the presentation was the long-term cost savings from reducing leased parking, and foregoing the decision to build new underground garages. This part of the proposal was based on estimates of Institute growth, after consultation with the Campus Planning office within the Facilities department. The long term cost implications were recognized, but there was some skepticism both as to the validity of the estimates, and how realizable they were. This was likely due to the separation in decision making between building new parking and changing the transportation subsidy policy. The costs came from the Parking and Transportation Office, whose charge is to "take care of" employees, while the benefits were mostly reductions in capital expenses. This diluted the focus on both the monetary and environmental ramifications of parking garages.

Additionally, the focus on environmental consequences of the transportation subsidy program resulted in less emphasis on the benefits to students. Fewer than 8% of students park on campus, and even fewer use their cars on a regular basis, least of all for commuting. Therefore, there is little to be gained for students environmentally; they are already Walking the Talk. The rationale for further subsidies of students is more related to the *in loco parentis* concept. This a twofold argument: 1) While students don't use cars now, they are likely to in the future. Developing a transit riding habit now will decrease their carbon footprint. As they go on to become leaders around the world, the impacts of their beliefs reach far beyond their own personal footprint on the planet. 2) The University has a responsibility to make sure that their students are safe, and make the most of the cultural assets of Boston. Marginal costs mean a lot to students, who do not have much money. A Universal Access pass would change their relationship to the city as a whole.

Neither of these arguments was put forward as strongly as they might have been. However, one suspects that these, too, would have missed their mark in terms of decision makers. The structure of decision making for students, especially if fees are involved, is separate from that for employees.

There were a number of follow up discussions in the intervening months, with administrators who have more decision making power regarding students, including the Dean of Students, among others. These discussions were focused on moving the entire project forward, rather than on moving the students separately. This left the decision makers without direct next steps to support the program, even if the *in loco parentis* framing of the issue was appealing to them, which it seems to have been.

5.3.3 The MBTA

During this time, the MBTA was re-engaged. Their initial concern was that MIT was attempting to negotiate discounted fares. In a subsequent meeting, that concern was allayed. The basic terms required that MIT would pay the full value for each fare, but would have the ability to charge its employees whatever it liked, in the same way that it currently subsidizes passes. The MBTA was also concerned that this would be perceived as a so-called “environmental justice” issue. If MIT employees would be able to get a better deal than people who purchased transit passes on their own. The ability of the CharlieCard to ensure that MIT would pay full fare for each and every ride was felt to be enough to keep this perception from taking hold.

The Mobility Pass group was concerned that reporting from the MBTA was not readily available, and therefore direct reliance on technology would delay the onset of any program. They proposed that MIT compensate the MBTA based on the estimates of usage in the survey data, with a set minimum payment and any additional payment based on reporting on actual usage. At the MBTA’s behest, it was resolved that rather than paying for usage on a consignment basis, MIT would provide pay-per-use cards to a subset of its employees, with an automatic refill, which would appear unlimited to employees, while ensuring that all fares were paid on a per-use basis. The MBTA further agreed that MIT could move people from pay-per-use cards to LinkPasses on a monthly basis. This would have effectively created a cap at the monthly rate, with a one-month lag that required administrative effort by MIT. The result was a lower cost than had been anticipated to MIT for the program. The prospects were bright.

5.3.4 Emerging Publicity

At the invitation of the EVP’s Office in March 2008, the Mobility Pass group—which at this point included the author, Mr. Attanucci, Secretary Salvucci, Mr. Brutti, and Mr. Owu, the Chair of the Transportation and Parking Committee—were invited to present the program at the monthly lunch for Department Heads, hosted by the President of the University, Susan Hockfield. Mr. Owu and Mr. Attanucci presented the program, as it existed at that point, with daily charges for parking on top of a monthly Mobility Pass fee that gave employees the right to park on campus and unlimited use of MBTA subway and bus services. There was tentative support within both the discussion at the luncheon tables, and in the group discussion afterward.

Based on the success of that meeting, at the behest of the EVP's Office, the Provost's Office for Institutional Research was engaged to run focus groups for interested employees. The goal was ostensibly to gauge reaction and acceptance of what was viewed as a relatively radical change to the transportation benefits program at MIT. These focus groups were scheduled for 3 times (all concurrent with meals, the lure offered for participation) during a single day, with approximately 100 participants per session. Participants were arranged at tables of 8 to 10, with an initial presentation to the group, followed by discussion at the table, and a single person reporting back to the session on the table's reactions to the proposal. This was approximately the same format as the Department Heads' meeting.

In the presentation to the employees who were part of the focus groups, there was a greater emphasis placed on both the difference in subsidy amount between parking permits and transit passes, and the behavioral change component, within a framework of individual cost savings. The program was designed to save money for all employees. It neither unduly rewarded those people who already took transit, nor increased the costs for those people who could not—or chose not to—reduce how often they drove to, and parked on campus. A such, the program was transformed to "all carrot, no stick." The focus was on the ability to self-mitigate increases in costs, especially through the lens of what were then very high, and increasing, gasoline prices.

The response received in the focus groups shaped the subsequent changes to the program. Employees were generally supportive, despite the fact that people who park at MIT on a regular basis were significantly over-represented, compared to their proportion in the population. The monthly cap on total expenditures was, and continues to remain, a popular concept. Not unexpectedly, people felt it gave incentive to change behavior, while ensuring that paychecks did not overly vary from month to month. There was a positive impression through much of the meeting that MIT was attempting to make changes to assist employees financially while encouraging them to Walk the Talk. Even those people who did not believe that it would change their own behavior, often indicated that they could see how it might help change others' behavior. The concerns were relatively minor compared to the overall level of support. They included (1) tracking and privacy; (2) whether MIT could handle the change administratively; (3) whether parking lots would have too much variance in how full they were; (4) whether employees would be able to move in and out of the program, especially those who only have 9 month appointments; (5) how lost passes would be handled; (6) whether MIT could do anything to improve MBTA service.

The decision to modify the proposed Mobility Pass was based on lessons learned from interaction with decision makers over the intervening months. Namely, that, although there was a desire to Walk the Talk, there was an aversion to significantly increasing the costs for employees. This was both because the low cost of parking was seen as a competitive advantage in the marketplace for employees, and because of the implicit promise of cheap parking that had been made to current employees. That is, the view of transportation benefits as a promise to care for employees outweighed the value of energy and emissions reductions. These modifications resulted in a program that was significantly less cost effective in the short run for MIT, as all of the savings now accrued to the employees.

While the decision to modify in the program in this manner was likely necessary, it ended up conflicting with the Institute's cost recovery goals from parking in the short term. The long-run savings for the Institute were based on foregoing new construction of parking and eliminating current parking leases. They were therefore conditional on the ability to manage parking more effectively—and with more of an eye toward cost recovery in the long run—than they had been throughout MIT's history. In this light, it is not as surprising now, as it was then, that the Institute reversed their tentative endorsement of the proposal subsequent to the focus groups, despite the overwhelmingly positive response.

5.3.5 An emerging consensus, and a sudden stop

Over the next two months there were a number of meetings between the Mobility Pass group and the EVP's office to clarify the issues raised by the employees, and discuss implementation details of the program, including projected costs. The EVP's Office remained unconvinced of the MBTA's ability to make the program work technically, the parking office's ability to administer the program, and how employees would react to the new incentives to change behavior. That is, they held to the meaning MIT being the provider of parking, or parental figure for its employees, and saw more risk in larger changes to the program than there was environmental reward. It was also apparent from these meetings that the EVP's Office had taken a different tack in their analysis, and believed that the program could be much more costly than the Mobility Pass group was projecting.

The EVP's office calculated costs based not on the actual usage by employees, but on the pass price. This particular misapprehension seems to be relatively common in the implementation of similar programs across the country. There was a similar analysis done by consultants for the UCLA Universal Access program prior to implementation, who projected costs almost 8 times what the eventual costs of the program were. They based their projections on the pass price, rather than on the actual usage of the program. (Brown, Hess, & Shoup, 2003) Since the core issue was the technical capacity to make the pay-per-use feature of the CharlieCard function in a Universal Access Pass context, the end result of these meetings was, at the beginning of August, a tentative agreement to proceed with a trial program with the MBTA to work out the technical details.

The proposed trial program had three goals: 1) To test the CharlieChip embedded in the MIT ID Card on a more widespread basis; 2) To verify the estimates of cost based on survey data with data on actual usage by students and employees; 3) To test the effectiveness of a free CharlieCard as the sole inducement for full-time parkers to reduce their usage of parking facilities. A meeting was scheduled between members of the EVP's Office and the MBTA, and plans to roll out a trial program in September advanced.

On Friday, August 8th, 2008, the MBTA sued MIT students Zach Anderson, RJ Ryan, and Allesandro Chiesa, the so-called MBTA hackers, to enjoin them from presenting their findings about vulnerabilities in the MBTA's fare system at the DefCon convention in Las Vegas that weekend. The MBTA also sued MIT as a party responsible for ensuring the appropriate conduct of their students. (McGraw-Herdeg & Vogt, 2008) All contact between MIT and MBTA ceased. The MBTA eventually settled their case with the students, and in fact hired the students to advise them on security vulnerabilities. However, despite little public notice of the fact, the suit against MIT was not dropped until January 2009, inhibiting any further discussion of a pilot program.

5.3.6 THE MOBILITY PASS RE-EMERGES

With a legal cloud no longer hanging over their relationship, the Mobility Pass group from MIT and the MBTA held a series of meeting in February 2009 to work out the technical details of a trial program. It was discovered that the pay-per-use methodology agreed upon in April 2008 would require changes to existing software. In the interim it was agreed that the MBTA could provide unlimited passes on a consignment basis, with MIT responsible for the total fare value at the end of each month. The MBTA also tentatively agreed to work with MIT to create the appropriate reporting capabilities to support the evaluation of a trial program.

With this information in hand, the Mobility Pass group made another presentation to the Transportation and Parking Committee in February 2009. Given the changed economic climate, the recommendation of the committee and its *ex oficio* members was to focus on programs that were budget neutral at all times, rather than requiring an investment upfront that would pay off in later years. The effect of this requirement is that the future savings from leased parking or new construction foregone cannot be counted as revenue generators. During that same meeting there was apprehension about continuing the 11% increase in parking charges for the coming fiscal year, given the wage freeze in effect for 50% of salaried employees. While the committee eventually voted to recommend the continuance of the 11% increase, they indicated that any experiments with parking price should be limited to mitigating economic pain for employees.

Given these requirements, a new proposal was put together to: (1) put a Charlie Chip in all MIT ID cards gradually over the upcoming fiscal year. (2) To move over a trial population to the modified pay-per-use program, where MIT would responsible for their fares at the end of each month on a consignment basis. (3) To move over all Occasional Parkers who have LinkPasses to this program immediately. (4) To move students over to the Semester Pass program, with its 11% discount. This saves MIT $6.50 per month per pass. Students would be induced to switch to the program, which by MBTA regulations requires a semester long commitment, by offering them a rate reduced by $3.50 per month. (5) Reduction in prices for a little used parking lots a 15-minute walk from the main campus, to measure the impact on demand. These programs were selected to be cost neutral to the GIB for FY09.

Based on the reaction from EVP's office to the focus groups, and the intervening discussion with the MBTA subsequent to the MBTA lawsuit, the current trial proposal is more modest in its aspirations to change behavior and Walk the Talk. It is still designed to offer only cost savings to employees, but no longer contains any significant modifications to the parking subsidy program, as it exists today. It is now designed to be cost neutral for the Institute in the short term, given the sensitivity to investment decisions that has become even more evident with the current budget crisis. As previously discussed, long-term Institute growth is no longer projected to be as rapid as it once was. There is less value placed on cost recovery of future construction, even as the average costs of providing parking are expected to increase significantly with the completion of the $40m+ Sloan Garage in the Summer of 2010.

The current proposal is positioned to be modest first step toward the larger goals outlined in the previous proposals. The emphasis has been shifted to improving the platform on which MIT offers their transportation subsidy program, namely by integrating the Charlie Chip in the MIT ID card. The positioning has very little to do with the meaning of transportation subsidies, but rather a different core value of the Institute, namely their position as a technological leader. It is focused on reassuring the EVP's Office that MBTA has the technological capabilities to match MIT's expectation of service delivery. The portions of the program that require investment—such as the marginal increase in card costs—are paid for by the portions of the program that are revenue positive. This is essentially a retreat from the program as representing core values at MIT. Instead it represents a behind-the-scenes approach to achieve efficiency while maintaining existing subsidies. It is inherently conservative and non-confrontational. It continues the "retain employees" mentality, while initiating only modest progress on a Walk the Talk environmental concern. Most fundamentally, it prioritizes a high certainty of technical functionality through proofing the MBTA's technical capability to bill on a monthly basis, before risking the embarrassment of a technical failure during a high visibility environmental campaign.

The portions of the program that continue to interact with how transportation subsidies are perceived at the Institute are the offering of the Semester Pass program for students and the reduced parking prices at one underutilized lot. These aspects of the program are only incidentally embracing the *in loco parentis* meaning of transportation subsides. They offer discounts to employees and students to induce mode shift and reduce emissions, but also to enable MIT to save money by more efficiently using its resources.

5.4 FUTURE MOBILITY PASS DEVELOPMENTS

The lesson is that the Mobility Pass program must meet a list of de facto requirements to win approval from decision makers on campus. It must (1) contain the environmental objectives and values of Walk the Talk, (2) fulfill the desire of MIT to be viewed as a benevolent provider for its employees and students, (3) provide competitive benefits in excess of the Institute's competitors, (4) meet the evident requirement for equality of costs, (5) be optional, and (6) increase cost recovery from providing parking, all while (7) insuring that it is revenue positive in both the short and long term.

These requirements can be met in Fiscal Year 2011, beginning June 2010. It requires the platform provided by the trial programs, and continuance of the 11% annual parking price increase. MIT has two basic options, which are non-exclusive: (1) MIT can encourage daily parking, and reduce demand through marginal incentives to park less often; (2) MIT can remove the marginal cost basis of paying for transit, and encourage a shift to more sustainable modes by ensuring that all students and employees have access to zero marginal cost transit. The decision should be made based both on how MIT wants to be perceived as a benefits providing employer, and how committed MIT is to Walking the Talk.

The 11% increase has been applied annually to Student and Commuter monthly parking, but only intermittently to Occasional parking. As can be seen in Table 5-1, the ratio for FY09 of the price of regular permit to that of a single day of Occasional Parking, after removing the permit fee for Occasional Parking, is 186 to 1, ignoring the additional charge for all days parked over 8 per month. In FY10, assuming an 11% increase in the Commuter Permit price, but no increase in the Occasional rates, the ratio will be 207:1. In FY11, the ratio will be 232:1. Occasional Parking is only charged for entrances or exits from Monday thru Friday, from 8am to 2pm. With 3 weeks of vacation, and 13 holidays, the absolute maximum number of days any person could be charged for parking in a year is 232.

Table 5-1. Ratio Of Commuter Permit Price To Occasional Parking Charge

	Annual Commuter Permit Fee	Annual Occasional Permit Fee	Daily Occasional Parking Charge	Annual to Daily Ratio
FY09	$786	$44	$4	186:1
FY10	$873	$44	$4	207:1
FY11	$970	$44	$4	232:1
FY12	$1,077	$44	$4	258:1

Because of these changes in the ratio of the annual price of parking to the daily price, one option MIT could pursue is to evolve to a daily parking system by phasing out its Commuter Permits at all gated lots. This will not result in a cost increase for any employee or student, fulfilling both the requirement to offer competitive benefits, and cost equality. There will be some short-term revenue loss associated with current inefficient allocations of campus parking spaces. Given the direct economic incentive to do so, that revenue loss by MIT can easily be mitigated by reducing the supply of leased parking, and reassigning those commuters to MIT lots. In fact, it is MIT's professed goal to end its parking leases as a cost recovery measure as soon as possible. With the opening of the Sloan Garage in 2010, the leases for more than 400 spaces will be ended. This program would provide an effective mechanism to reduce the remaining leased spaces.

Those people who currently park less than the maximum chargeable days annually would see savings from the transition. If these people who currently park less are, or are perceived as being, at the higher end of the pay scale (Faculty), this might raise a concern about the equity implications of this program. However, these concerns might be mitigated by the increased availability to combine parking and transit benefits. As shown in Table 5-2, those people who could park fewer than 12 days per month (3 days per week) in FY11, would be able to also purchase a transit pass, and still pay less than the equivalent monthly permit fee. If they are not taking transit at all currently, this would be financially neutral to them. If they take transit even occasionally now, this would result in cost savings. If this results in reduced demand for parking at MIT, some of the cost savings from eliminating leased parking could be invested in reducing the cost of transit passes further. These reductions would allow more people the opportunity to switch to transit on an occasional basis, both to Walk the Talk and save money. If leased parking savings materialize, than combination with a low-cost Universal Access Pass seems achievable, while still keeping the "do no harm" principle of not increasing price increases above the currently planned 11% annual increase.

Table 5-2. Ratio Of Commuter Permit Price To Occasional Parking Charge

	Monthly Commuter Permit Fee	Monthly LinkPass Cost	Occasional Parking Charge	Number of days parked per month where Occasional Permit and LinkPass combined cost less than Monthly Commuter Permit
FY09	$65.50	$29.50	$4/day + $44/year	8
FY10	$72.75	$29.50	$4/day + $44/year	10
FY11	$80.83	$29.50	$4/day + $44/year	12
FY12	$89.75	$29.50	$4/day + $44/year	14

This program gives economic incentive to reduce the number of days driven to all people, equally. It also gives MIT flexibility to change the program within an annual 11% price increase in more creative ways. For example, rather than an across the board 11% increase, MIT could raise the permit charge, and reduce the additional cost for transit passes. Alternatively, MIT could raise the marginal rate for days parked over 8 per month by 22%. This would have the same consequences for cost recovery, would not penalize anyone as compared to the 11% annual increase in

Commuter Permit rates, and would give equal access to cost mitigation by all employees and students. Those people without access to transit can share rides on an ad hoc basis, or if encouraged by their department, telecommute. The ability to mitigate those cost increases by parking less aligns the economic incentives of MIT's employees with MIT's own long term goals to increase cost recovery from parking. Even if MIT does not continue to expand its personnel, it will continue to see demand for alternative uses for its lots, whether for new buildings and laboratory space, or increased green space. Without a policy to decrease demand for parking from employees, these demands will reduce the available parking on campus, necessitating new spots be leased or built.

Progress on Waling the Talk requires low cost universal transit access for all employees and students. For students a charge folded into tuition or student fees is likely the most effective way to proceed. With such a charge in place, students could be given the option to opt out in a manner similar to that found at the University of Washington; returning the pass or otherwise contacting the transportation office, for example by the creation of a simple web based mechanism. Even if given the opportunity to opt out, participation is likely to be above 70%, depending on the charge. Given the positive experience with student participation in decision making at Universities across the United States, this might achieve more support and participation if it was contingent on the student body approving this charge, either through a voting process, or some other means.

For those employees who park, zero cost transit would be the most effective means of reducing demand for parking in the long run, and thus would save money. Given the constraints to be revenue neutral in the short run, MIT can create an optional Limited Access transit pass. This would cost employees $15/month, and allow employees to commute round trip up to 10 times per month. With the proper conditions, including automatic upgrades to the full LinkPass if the trip limit was exceeded, it would avoid significant revenue loss from those people who currently purchase a LinkPass, while encouraging the use of environmentally sustainable modes that also save MIT money. Since it is available to all employees, it meets the equality of cost opportunity requirement. It is a substantial new benefit for employees that is revenue positive for the Institute, in combination with the active management of current LinkPass holders on MIT pays-per-use cards.

The proposed programs are either optional, or in the case of students, based on democratic participation. As such, they are not disruptive to MIT's image as a benevolent provider. Instead, they enhance its ability to provide a competitive benefits package, while aligning economic incentives for both employees and the Institute with environmental goals for the first time.

It is important to observe that given the complexity of the objectives, a central requirement of both the budgetary and environmental goals is the disciplined phasing out of leased parking spaces. If parking were priced at $10/day, close to but below market rate, demand would fall significantly (and there would be many unhappy employees). Reducing the parking supply by eliminating leased spaces would make supply less, rather than more flexible, especially without mitigation measures. Simply changing the pricing or reducing the supply may seem to be desirable policies, but there are political constraints that make theses policies difficult if not impossible to implement on their own. The environmental and cost recovery goals at MIT need to be met within a politically feasible path, using its regulatory power in combination with new transit subsidy "carrots," in order to make the transition acceptable and achievable. If the employee's options improve, but the supply of parking at MIT continues to be priced far below market prices and exceed the market equilibrium that would occur without subsidies (the "shadow price"), then the spaces will continue to be utilized, there will be pressure to use more, and the congestion and emissions goals will not be met.

5.5 Conclusion and Policy Options To Be Analyzed

The remaining sections of this thesis quantify the degree to which intrapersonal variability (mode bundling) already occurs, and create a model to predict the mode shift and cost effects of changing policy to encourage this behavior, under the rationales detailed above. As this chapter has shown, the Mobility Pass has undergone continuous change in the 5 years since it was initially proposed. These modifications have been intended to fit into a changing conception of the goals of the Institute, changing fiscal conditions, and new developments in available technology. To meet the goals of the Institute requires designing a program that is revenue neutral in the short-run, and meets environmental and equity concerns in the long run. The policies analyzed in Chapter 7 begin with a straight Universal Access pass, where MIT pays the MBTA for all uses by its enrolled employees and students. This program is analyzed under a number of different formulations, in order to ascertain the effects of the policy options available to MIT. (1) A mandatory program for all students and employees, with equal costs, both including full access to Commuter Rail, and with a separate payment structure for a Commuter Rail add-on. (2) A constraint of equalizing the after tax costs to students and employees, since student payments do not qualify for transportation fringe treatment. (3) Differential costs for students and employees based on the aggregate usage by these two groups. (4) An opt-out regime for both students and employees.

A required program is more difficult to justify under a choice doctrine for employees than for students, since there is no mutually agreed upon democratic body that imposes fees on employees, while there is a student government. Thus, Chapter 8 also analyzes a number of options that increase the incentives for employees to participate in zero marginal cost transit pass program. (1) The Mobility Pass as a mandatory component of a monthly parking permit, both with and without an additional fee. (2) The Mobility Pass as an optional component for people with monthly parking permits. (3) Eliminating monthly parking permits in favor of daily pricing for parking.

The final policy option analyzed is the Limited Access Pass, what UW has called a Green Pass. This would allow participants a limited amount of transit rides on a monthly basis in return for a lower cost. By lowering the monthly cost, this may increase the incentives for people who drive to try transit, in the absence of the political will to impose any of the other regimes proposed. Even if MIT chooses one of the other policy options, this limited access transit pass has an appeal to those people who mostly use non-motorized transportation, but also make use of the MBTA system. It can serve as a stepping zone to a Mobility Pass that includes Universal Access by increasing the desirability of options, rather than via coercion.

All of the policy options analyzed allow employees more flexibility to optimize their commuting patterns for their desired commuting costs, activities, and environmental impact. These options align employees' incentives with MIT's incentives, MIT with the MBTA, and all of them with the City and region. The difference between them is in political feasibility and cost- and environmental-effectiveness.

6 MODE CHOICE AT MIT

The myth of the single mode man is that, given a job and home location, people choose the same commute mode each day. Thus far this thesis has shown how model sampling techniques, the federal tax code, employer transportation subsidies, and the particular policies at MIT use this assumption and therefore cause and reinforce single mode behavior, frustrate the policy objective of reduced auto use. This chapter analyzes these patterns at MIT, and thus provides the basis for changing this behavior.

It begins by exploring mode share at MIT, within a weeklong, rather than daylong sample. This reveals that a substantial portion of employees at MIT who are neither transit nor auto captive behave in a manner antithetical to the myth. It then proceeds to look at mode choice variability both within a week, and between weeks, to establish the stability of bundling behavior, and the evidence for mode blending over a period longer than 5 days. This chapter continues by exploring mode switch both for people who completely change their mode, and for people who add or subtract modes to their menu of weekly mode choice. The change in exogenous factors has been too large in the intervening years between surveys to properly attribute any mode switch to either exogenous changes or MIT policy changes. Nevertheless, it provides insight into behavioral trends.

Comparing behavior between benefits eligible and ineligible employees establishes that transportation subsidies do in fact change behavior. MIT's transit subsidy results in increased revenue for the MBTA and improved equity for transit riders, but it increases ridership to a lesser degree than it increases the number of people with monthly passes.

This Chapter concludes by describing the demographic variability in mode choice. This baseline allows for a more complete model of the antecedents of mode choice, and application to policy interventions in Chapter 7.

6.1 MODE SHARE: A MORE COMPLETE VIEW

The variability of mode choice in a given week at MIT is an entry point to a more detailed analysis. As seen in Table 6-1 and Table 6-2, variability between days in travel to MIT is not insignificant in magnitude.[4] Some variability is based on expected patterns—there are an additional 5% of employees who do not come to campus on Fridays, drawn equally from each mode—but some is less easily explained. For example, public transit sees the highest percentage mode share on Tuesday, while Wednesday is the day for driving, and Monday for Walking or Biking. Since this is a sample of the exact same people each day, the only conclusion is that

[4] The results presented throughout this chapter are re-weighted to the entire population of onsite employees who are eligible for transportation benefits, with weighting factors based on the type of employee, and the type of benefit they receive, to correct for biases in the survey. The full methodology behind this weighting is described in Appendix 1.

there is variability in travel behavior. If this were the limit of the analysis, the conclusion would be that, with the exception of Friday, there are 1-2% of people who vary the mode of their commute between days. This measure underestimates the amount of variability that actually exists.

Table 6-1. Daily Employee Mode Share, 2008, Weighted

		Monday	Tuesday	Wednesday	Thursday	Friday	Average
01	Drove alone the entire way	2,348	2,387	2,443	2,435	2,279	2,379
02	Drove alone, then took public transportation	472	452	464	450	404	449
03	Walked, then took public transportation	2,146	2,267	2,289	2,247	2,155	2,221
04	Shared ride/dropped off, then took public transportation	236	254	234	232	215	234
05	Bicycled and took public transportation	101	119	97	106	104	105
06	Rode in a private car with another person	465	482	485	498	454	477
07	Rode in a private car with 2-6 commuters	93	84	96	82	92	89
08	Rode in a vanpool or private shuttle	39	41	47	36	35	39
09	Dropped off at work	81	91	72	86	81	82
10	Bicycled	712	689	611	651	576	648
11	Walked	716	710	710	714	697	709
12	Out of office (sick, vacation, jury duty, business trip)	401	354	357	381	469	392
13	Scheduled day off (e.g. weekend)	223	130	156	135	330	195
14	Worked at home	171	150	170	142	346	196
15	Other, please specify	204	197	190	215	173	196
16	Took a taxi	18	20	5	19	19	16

Table 6-2. Mode Share By Day Of Week, End Commute Mode Only, Employees, 2008, Weighted

	Monday	Tuesday	Wednesday	Thursday	Friday	Average
Drive Alone	27.9%	28.3%	29.0%	28.9%	27.0%	28.2%
Public Transit	35.1%	36.7%	36.6%	36.0%	34.1%	35.7%
Rideshare	8.0%	8.3%	8.3%	8.3%	7.8%	8.2%
Pedestrian (Bike / Walk)	17.0%	16.6%	15.7%	16.2%	15.1%	16.1%
Not on Campus	9.4%	7.5%	8.1%	7.8%	13.6%	9.3%
Other	2.6%	2.6%	2.3%	2.8%	2.3%	2.5%

6.1.1 VARIABILITY: BUNDLES

To measure variability on the disaggregate level requires the concept of a "mode bundle." A mode bundle is the collection of modes a person uses to travel in a given time period. In order to pinpoint the variability of concern—the use of a mode in a given week—bundles are defined based on the binary selection for each of the 4 main journey-to-work modes in a given week; drive alone, rideshare, public transit and walk/bicycle.

As shown in Table 6-3, 77% of employees used a single mode to commute to work, 4% did not come to campus, or responded "Other," and 19% of employees used multiple "final" modes to commute. The final statistic bears repeating. Almost 1 in 5 employees commuting to the same location used different modes on different days in a given week in 2008. This does not imply that variability is random. It is likely generated by different activity patterns during the week. Variable and irregular behavior are not synonymous. Recall that employees are subject to policies at MIT that, for the most part, encourage stability in mode choice. Mode bundling must have inherent value if it is pursued despite an incentive structure to the contrary.

Table 6-3. Recurring Bundles, Weighted, 2008

	Frequency	% of Population
Transit	2,606	30.9%
Drive	2,284	27.1%
Pedestrian	1,055	12.5%
Drive + Transit	516	6.1%
Rideshare	500	5.9%
Transit + Pedestrian	364	4.3%
Other or Not on Campus	351	4.2%
Drive + Rideshare	218	2.6%
Transit + Rideshare	181	2.1%
Drive + Pedestrian	154	1.8%
Rideshare + Pedestrian	99	1.2%
Drive + Transit + Pedestrian	30	0.4%
Drive + Transit + Rideshare	30	0.4%
Transit + Rideshare + Pedestrian	28	0.3%
Drive + Rideshare + Pedestrian	11	0.1%

The specific choices made by employees are also of interest. More employees alternate modes between drive and transit in a given week than rideshare on a daily basis. More than twice as many employees combine public transit and driving alone than combine rideshare and driving alone. This implies that the mode bundling opportunities for drivers and transit users are higher than for ridesharing. More people rideshare in combination with another mode than rideshare only (6.5% vs. 5.9%). Whereas people who are converted to take transit occasionally, might take transit all the time in a subsequent time period, this comparison points to the difficulties in converting occasional ridesharers to full-time ridesharers. There are more opportunities for SOV reduction than previously assumed. Fully 2% of the people who drive, also take the option to bicycle occasionally. People have more flexibility than policies assume.

6.1.2 How Primary is Primary?

Another way of looking at day-to-day variability in mode choice is the degree to which self-defined primary mode share represents a given week's behavior. Primary mode share reveals additional variability in travel behavior beyond that found within a single week. This measure is a complement to the bundles defined previously. For instance, the primary mode may not have been used during the past week. This would permit inference that there is more variability than accounted for in bundles based solely on the prior week's trips.[5]

Table 6-4 shows that 8% of people who drove as their primary mode did not drive to MIT in the surveyed week. This is a slightly higher percentage of non-usage of the primary mode than found for other modes. However, everyday usage of driving by people who mainly drive is higher than other modes. People who drive do so more regularly than people with other primary commute modes, but even so are quite variable in their behavior. 93.4% of people who commuted to MIT used the end mode they indicate is primary (for example, they took transit, even if they did not necessarily bicycle to transit) in the week prior, but only 77.6% of people used it exclusively. 16.8% of employees used a mode in addition to their primary commute mode in the week prior. Those who did not use their primary commute mode at all can be attributed to the variability that exists between weeks. Up to an additional 6.6% of people are multimodal by this measure.

Table 6-4. Primary Mode Vs, Mode Usage In Prior Week, Employees, 2008

	Same End Mode	
Prior Week	**Always**	**Ever**
Drove alone entire way	82%	92%
Drove alone, then took public transportation (PT)	65%	94%
Walked, then took PT	76%	96%
Shared ride/dropped off, then took PT	73%	96%
Bicycled and took PT	57%	80%
Private car with addl. per.	64%	86%
Private car with 2-6 ppl.	77%	96%
Vanpool or private shuttle	43%	82%
Dropped off at work	66%	98%
Bicycled	66%	96%
Walked	72%	95%
Total	80.7%	93.4%

[5] Since there can only be a single primary mode, this measure does not allow for situations where there is no primary mode; where the preference is for using multiple modes. Furthermore, primary is not defined – it could mean most frequent, or most desirable.

6.1.3 Are bundles stable? The evidence for variability between weeks and years

If multimodalism is an alternative to the single mode man, then people who currently use multiple modes should have behavior that is stable over time. If multimodal behavior is just an artifact of a random week, than it is futile to target. On the other hand, if multimodalism represents behavior that appears at multiple points in time, over multiple weeks, than it is legitimate to think removing disincentives can encourage it.

This section looks at the subset of people who have answered the survey all three of the years for which data is available; 2004, 2006 and 2008. If the same amount of mode choice change occurs between 2004 and 2008 then the additive change between 2004 and 2006 and 2006 and 2008, then the conclusion is that the main driver is change over time. The degree to which there is less change between 2004 and 2008 than the additive change between two-year intervals is the extent of the week-to-week variability in bundling behavior.

The most direct way to look at this effect is by defining those people who are changing within each period. People have one of 5 statuses between any two periods: (1) they can be stable in their behavior (use the same modes in both weeks), (2) they can be adding modes, (3) they can dropping modes (or unbundling), (4) they can be doing both, or (5) they can be changing their mode completely.

Comparisons between years can seem significant in aggregate, but to understand real change requires examination at the disaggregate level. Mode bundles that seem stable between years have actually changed, and then changed back between weeks of that year. Mode bundles that seem to have changed are actually stable, but mis-categorized in the first place. The "total" row in Table 6-5 shows that 84% of mode choice is stable over time for people with only a single mode in their bundle, whereas 70% of mode choice is stable for people with multiple modes in their bundles. That is, people with a single mode show slightly more stability, but there is still a significant amount of stability in multimodal behavior: these multimodal patterns represent real patterns, not fleeting moments because of a unique activity pattern in the week in question. Slightly more than 30% of the apparent complete mode switch between years is in fact bundling behavior between weeks (the additive changes from 2004 to 2006 and 2006 to 2008 vs. the total number of people changing completely). It appears to be complete mode switch because behavior is only measured for a single week. Both the group that is adding and the group that is dropping modes (the second and third data rows) show more stability than the mode switchers. These behaviors are more likely to represent actual change. The group that is stable in mode choice between 2004 and 2008 hides 13% of bundling behavior between weeks (100% minus the weighted average of single and multiple mode bundles stable throughout all periods).

Table 6-5. Bundling Stability Over Time By Modes In Bundle In 2004

Modes in Bundle in 2004	Bundle Stability	2004 to 2008	2004 to 2006	2006 to 2008	% who made this change in one year, and were stable in the other
1 Mode	Stable	995	901*	901*	91%
	Adding Only	195	49	98	75%
	Changing Completely	350	93	158	72%
	Total	1,540	1,043	256	84%
2 Or More Modes	Stable	320	235*	235*	73%
	Adding Only	69	19	35	78%
	Unbundling Only	228	125	54	79%
	Adding + Unbundling	46	7	5	26%
	Changing Completely	98	20	35	56%
	Total	761	406	129	70%

* Those people whose behavior is stable between 2004 and 2008, and in any other 2 year period are stable by definition in the other.

In Table 6-5 it can be seen that for those people who had multiple modes in their bundle in 2004, and the same modes in 2008, 27% changed modes in the interim. For example, if someone drove and took transit in the week sampled in 2004 and 2008, they might not have driven in the week sampled in 2006, but still took transit, and then did both again in 2008. 57% of that variability for people who have multiple mode bundles that are stable is week-to-week variability that does not represent an additional mode (they dropped one of the modes in their bundle in the interim, and then added it back). 28% is people who added a third mode in the interim, and then dropped it. The remainder is people who changed completely in the meantime and then changed back.

The earlier conclusion was that approximately 20% of people are multimodal in a given week. Of those people who had only a single mode in 2004, 5% used multiple modes in 2006, and 5% more used multiple modes in 2008. In other words, a small segment of the population who seem to be bundling are actually people who regularly use only one mode, while some of the population who seems to be using a single mode are actually bundling between weeks. There are therefore an additional 5-10% of people who are multimodal between weeks.

6.1.4 VARIABILITY: TRANSIT TRIPS

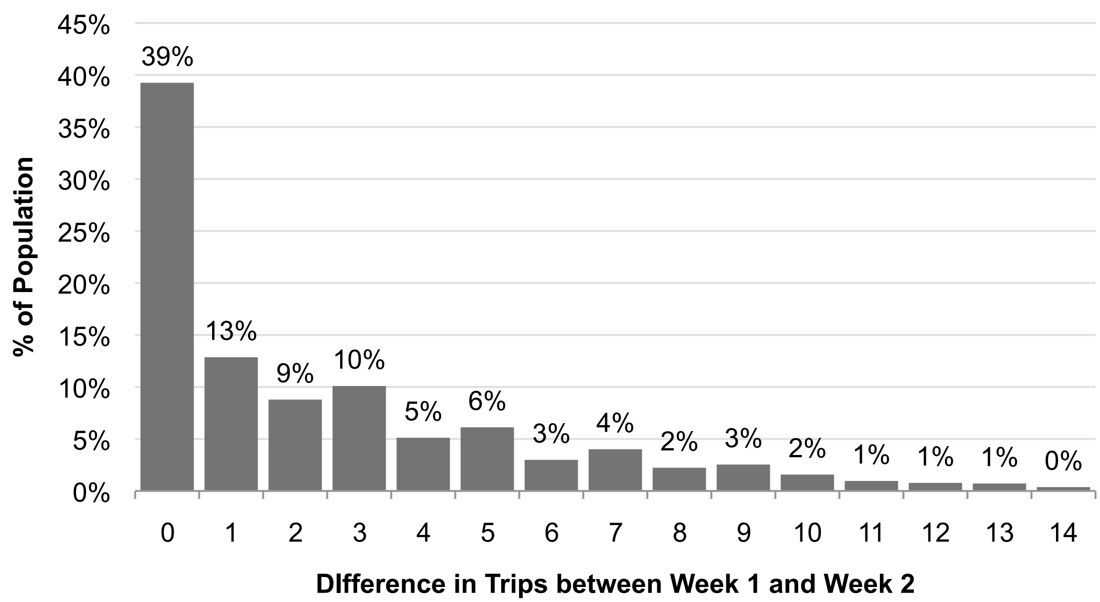
The previous analysis required inference about week-to-week variability from the difference over time between three periods. There is also data on two weeks of transit trips from the 2008 survey. This allows a direct look at variability in frequency of use, within a single mode.

A single week of trips is 93% correlated with a separate week of trips. As can be seen in Figure 6-1, 61% of the population varies the number of transit trips they take between weeks, and 29% show variance of 2 or more round trips between weeks. However, as shown in Table 6-6, there is much less difference on an aggregate level; between each week's samples there is less than 1% variability in mean trips. This variability may be affected by the bias to answer questions similarly across weeks. These questions were asked in the same survey, taken at the same time—they represent the memory of the person of the trips they took two weeks ago. Some of the bias towards consistency is removed because the question was asked not on the aggregate level— how many transit trips did you take last week?—but on a more disaggregate level—how many times did you board X,Y and Z routes in the past week?

Table 6-6. Variability In Transit Trips Between Weeks

	Mean	Std Deviation	95% Confidence Lower	Upper
Week 1	5.272	6.888	5.12	5.42
Week 2	5.236	6.953	5.09	5.38

Figure 6-1. Distribution of Variability in Transit Trips between Weeks



6.2 Change Over Time

21% of people indicate that they have changed their primary commute mode in the last year. That change is dynamic. People switch from driving alone to public transit, but they also switch from public transit to driving alone, or walking. Each change represents an opportunity for behavior modification to more sustainable travel modes.

As can be seen in Table 6-7 and Table 6-8, the net decrease in driving alone as the primary mode is 2.2% in the last year. Mode switch is cascading. Fewer people move directly to walking from SOV travel, and vice versa. 4.1% of people moved from SOV to Public Transit, but only 1.1% moved to ridesharing from SOV travel.

While transit is the biggest attractor of people who are changing their primary mode, it is not the end state. It gains 1.4% on net from SOV commutes, and 0.1% from Rideshare, but loses 0.6% to walking and biking. Keep in mind that primary mode does not mean that all trips are changing, only that what the commuter considers to be their dominant or preferred mode is changing. 20% of people who indicate that their primary mode changed, actually changed within a given mode—for example from "walking to public transportation" to "biking to public transportation."

Table 6-7. Change In Primary Mode, By Former Mode, Employees, 2008

Former Mode	Current Mode				
	SOV	Public Transit	Rideshare	Pedestrian	Decrease
SOV		4.1%	1.0%	1.1%	-6.2%
Public Transit	2.7%		0.8%	2.2%	-5.7%
Rideshare	0.7%	0.9%		0.2%	-1.9%
Pedestrian	0.6%	1.6%	0.2%		-2.4%
Increase	4.0%	6.6%	2.1%	3.5%	

Table 6-8. Net Flow In Primary Mode, By Former Mode, Employees, 2008

Former Mode	Current Mode		
	Public Transit	Rideshare	Pedestrian
SOV	1.4%	0.2%	0.5%
Public Transit		-0.1%	0.6%
Rideshare			0.0%

Table 6-9 shows that people who have moved recently are more likely to have changed their mode. However, 1 in 7 of those people who have not moved in 15 years changed their primary commute mode. You can teach old dogs new tricks.

Table 6-9. Primary Mode Change By Move Year, Employees, 2008

Most Recent Move Year	1994 or earlier	1995 to 2000	2001 to 2004	2005 to 2008	Total
Changed Primary Mode	14%	16%	17%	27%	21%

Table 6-10 compares the movement in transit benefits over time directly. 36% of people who did not elect to receive a benefit in 2006 changed their election in the intervening 2 years. Overall, 20% of people changed the type of benefit they received. Those people with a Monthly Parking Permit were the least likely to change. Of those who did, approximately 50% moved to a transit pass with an Occasional Parking permit, and 25% moved to a transit pass only. Mode switch and primary mode are entwined, but both show significant variability. With monthly benefits, people change their choices to meet their expected activity pattern. They need to continuously optimize and re-optimize their choices based on endogenous and exogenous factors.

Table 6-10. Transportation Benefit Received In 2006 Vs 2008

	2008 Benefit							
2006 Benefit	**None**	**Bus / Link Pass**	**CR Pass**	**Occl Permit + Bus / Link Pass**	**Occl Permit + CR Pass**	**Occl Permit Only**	**Monthly Permit**	**Same Benefit**
None	64%	19%	1%	2%	0%	4%	9%	64%
Bus / Link Pass	5%	83%	4%	6%	0%	0%	2%	83%
CR Pass	4%	7%	78%	0%	8%	0%	3%	78%
Occl Permit + Bus or Link Pass	2%	10%	1%	71%	4%	5%	7%	71%
Occl Permit + CR Pass	0%	0%	10%	4%	80%	2%	4%	80%
Occl Permit Only	7%	1%	0%	12%	5%	65%	9%	65%
Monthly Permit	2%	2%	1%	3%	3%	4%	87%	87%
Total	11%	21%	5%	8%	5%	6%	43%	80%

6.2.1 POPULATION CHANGE, OR CHANGE BY EXISTING EMPLOYEES?

Using panel data allows examination of the behavior of those people who were surveyed in all of the survey periods, and comparison to those people who were new to campus, and those who left in each period.[6] This results in 6 groups of interest. Examining mode share and bundle composition of these groups allows insight into whether the change that is taking place is due to a change in the composition of the population, or due to a change in individual behavior.

1. **Answered 04, 06, 08.** (1,644 observations) Their behavior can be tracked year-over-year.
2. **Answered 06, 08.** (1,286 observations) This data is good for comparing 2006 and 2008, but not necessarily for making assumptions about people who were new to campus between 2004 and 2006, since population data for 2004 is not available, and thus no definitive conclusions can be made about whether they were not on campus in 2004, or simply did not answer the survey.
3. **Answered 04, 06, Left Campus 08.** (331 observations) Allows a comparison between 2004 and 2006, for those people who left MIT after 2006.
4. **Answered 04, Left Campus 06, 08.** (757 observations) Allows a good measure of those people who left after 2004.
5. **Answer 06, Left Campus 08.** (723 observations) This data allows a good measure of those people may have joined after 04, and left after 06
6. **Not on Campus 06, Answered 08.** (1588 observations) This allows measurement of behavior by those people who were new to campus in 2008.

[6] In the following measures, those who “left” in 2006, or 2008 are those people who left MIT completely, not those people who remained at MIT but simply did not answer the survey.

Figure 6-2 shows that those people who left after 2004 had lower drive mode shares and higher transit mode shares than those people who stayed. Those people who were here only for 2006 had much higher transit mode share than those who were here for all three years. Those people who were new to MIT in 2008 had the highest transit mode share. To some degree, the increase in transit mode share year-over-year is due to a changing population. New employees who are more likely to use transit are replacing employees with higher drive alone mode shares. This should be not be construed to discount the importance of transportation subsidies in affecting mode shift. Those people who joined before 2004 were confronted with a very different subsidy regime than the people who joined in 2008. To some degree, the change seen in Figure 6-2 can be ascribed to a younger population replacing an older population. It can also be assigned to the effect of the benefits available to that new population when they were making their long term decisions about where to locate, how many cars to own, and their choice of modes, in order to meet their desired activity patterns.

Figure 6-2. Mode Share (Use Mode Every Day) By Respondent Group

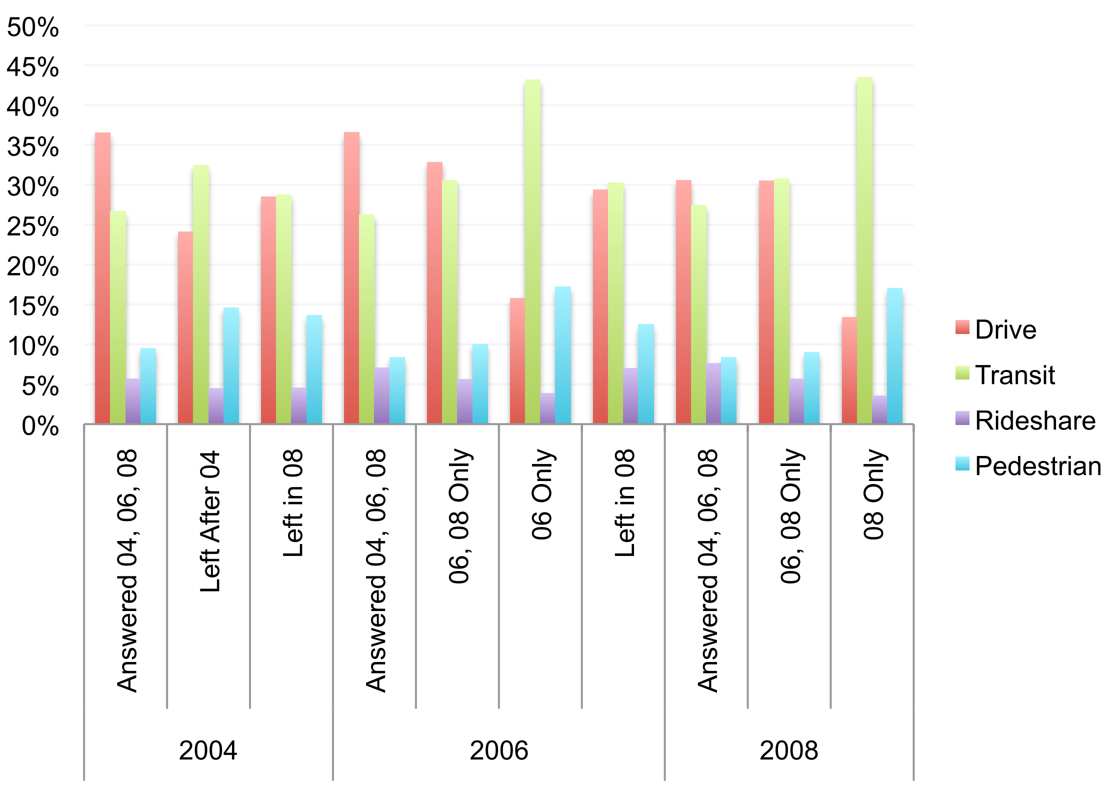
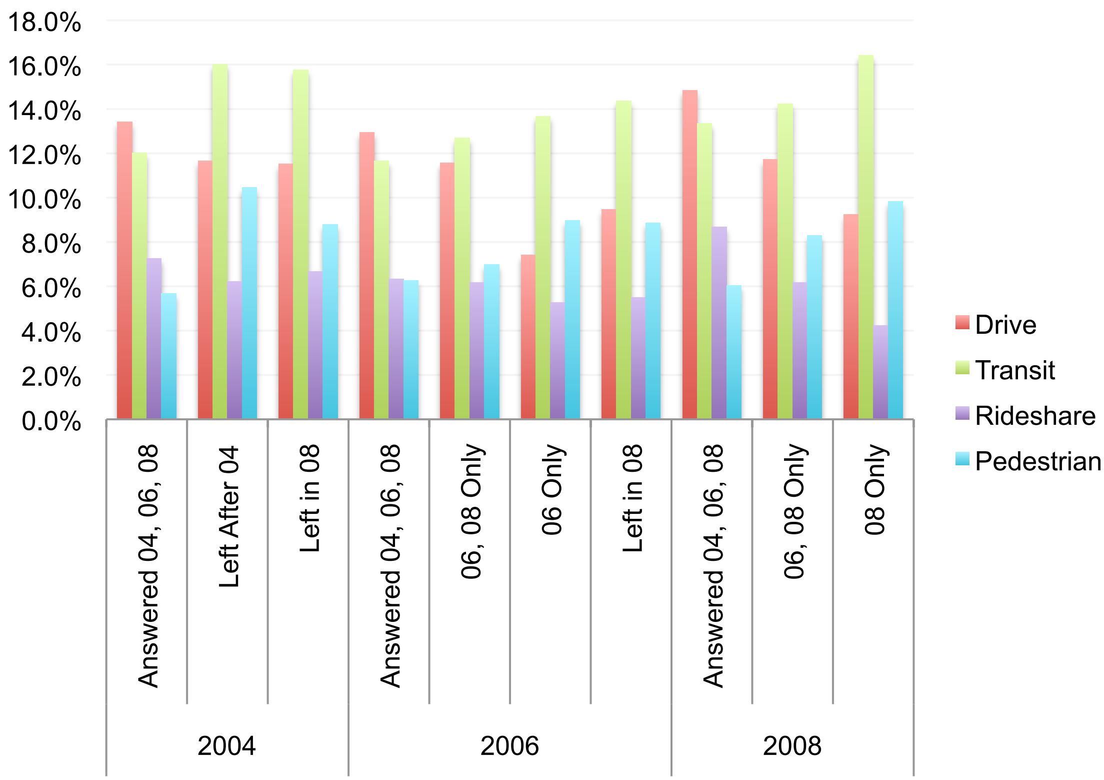


Figure 6-2 shows that the effect of the transportation subsidies on the trackable groups is less significant than the overall change for the population. There was almost no change in the number of people who drove, took transit, shared a ride, or walked and bike consistently between 2004 and 2006 within any of the trackable groups. Drive mode share for people who drove every day of the week decreased significantly from 2006 to 2008, but as can be seen in Figure 6-2, there was no accompanying increase in everyday transit mode share. Instead, as seen in Figure

6-3, there is an apparent increase in the number of people who substitute one or more days of driving with transit and ridesharing. this may indicate an attempt by employees to increase the amount of flexibility they have, within the transportation benefits that are offered to them. The patterns for those people tracked between 2006 and 2008 are very similar. While there have been policies to encourage mode switch, and some evidence that change is occurring in the aggregate, it has thus far not made a particularly large dent in disaggregate behavior. Transportation subsidy policies have been put in place to encourage people to change their commuting patterns on a wholesale basis. The evidence does not support their effectiveness.

Figure 6-3. Mode Share (Use Mode At Least Once In Prior Week) By Respondent Group



6.3 The Effects Of Subsidy

6.3.1 Aggregate Patterns

Chapter 4 showed that MIT's policies mostly maintain exclusivity between transportation benefits. This encourages employees to use that single, subsidized, mode more often than they otherwise would. The preceding statement can be split into two hypotheses. (1) People sort themselves into the benefits they receive by which mode they prefer. (2) Those benefits subsequently encourage them to travel to MIT via non-primary modes less than they otherwise would. This section examines the first hypothesis. It explores the degree to which benefits sorting does not fit the flexibility in mode choice that people demonstrate. This in turn points to the degree to which the second hypothesis might affect behavior.

Table 6-11 uses three measures of the degree to which people are sorted into mode buckets by the type of benefits they receive. (1) Whether they indicated that the mode was *Primary*; (2) whether they used the mode each day of the previous week (*Always*); and (3) whether they used the mode at all in the previous week (*Ever*). 4% of people who pay for a monthly Commuter Parking Permit use a different primary mode[7], 3% take transit or walk every day, and 11% sometimes use a different mode. For people with a LinkPass (unlimited access to MBTA Bus and Subway), 3% drive or rideshare primarily, 1% always drive or rideshare, and 9% sometimes do so. The bigger difference from driving is that 16% of people with transit passes primarily walk or bike, 13% always walk or bike, and 24% ever walk or bike. Transit riders (who do not park at MIT) do not maximize the value of their benefits for commute purposes to the same extent that drivers do. This may be due to the discounted price they receive. Because the transit pass has a known value, as opposed to per-ride fares, people may maximize the value of the benefit up to the price they pay, rather than the full value of the pass.

Table 6-11. Mode Usage By Type Of Transportation Benefit Received

		None	Bus Pass	Link Pass	Commuter Rail	Occasional + Transit Pass	Occasional Permit	Carpool Permit	Commuter Permit
Drive	Primary	7%	4%	1%	1%	9%	36%	6%	82%
	Always	5%	3%	0%	1%	5%	26%	3%	73%
	Ever	9%	11%	3%	5%	43%	52%	18%	84%
Transit	Primary	32%	75%	79%	91%	79%	14%	3%	2%
	Always	26%	58%	66%	83%	43%	8%	5%	2%
	Ever	38%	86%	83%	91%	85%	21%	9%	7%
Rideshare	Primary	5%	0%	2%	1%	3%	17%	86%	12%
	Always	4%	0%	1%	1%	1%	8%	69%	8%
	Ever	10%	3%	6%	3%	9%	24%	88%	15%
Pedestrian	Primary	52%	16%	17%	2%	6%	29%	4%	2%
	Always	43%	11%	13%	1%	3%	14%	3%	1%
	Ever	56%	33%	24%	2%	8%	32%	7%	4%
Total		1,526	68	2,047	396	902	461	204	2,760

As expected, people with an Occasional Parking Permit and a transit pass drive less than people with just an Occasional Permit and people with a monthly Commuter Parking Permit, and take transit less than those people who just have a transit pass. They are the most multimodal employees at MIT. In Table 6-11, it is evident that 12% of people with both a permit and a pass indicate that driving is their primary mode, but only 6% drive everyday. 52% drove at all in the previous week. Some of those people who park everyday, who have both an Occasional Parking Permit and a

[7] This analysis includes those people who rideshare as driving primarily.

transit pass, seem to provide evidence of week-to-week variability. The others may be exploiting the fact that enforcement of the price increase after 8 days of parking has not been prioritized. By policy, if an employee with an Occasional Permit drives everyday they pay $4 for the permit each month, $4 for each day they park up to 8 days, and $10 thereafter. It is cheaper than a monthly permit if they expect to park fewer than 11 days per month. The *de facto* policy has been that those days Occasional Permit holders park after the 8th day of each month actually cost $4. This then means that Occasional Parking is cheaper than a monthly permit if they park fewer than 16 days in a month. In other words, it may well be rational for someone who drives every day, but tends to work a 4-day week, to have an Occasional Permit. In fact, of those people who only have an Occasional Permit (as opposed to also having a transit pass), 53% indicate that they primarily drive, 34% drive every day, and 84% drove at all in the previous week. This is also a sensible choice for second-shift employees, since people who enter an MIT lot after 2:30 on a weekday do not pay a daily fee. Table 6-11 also shows that transit usage for those people who have an Occasional Permit and a transit pass is similar to those who just have a transit pass. These people are slightly less likely to use transit as their primary mode, and significantly less likely to use transit every day, but just as likely to have used transit at all in the previous week.

The last group is the 18% of employees who do not participate in any transportation benefits program. This is only an economically rational decision if the person does not use transit at least 12 one-way trips per month, and never parks on campus. There is limited on-street parking available, limited visitor parking for a $12 daily fee, and parking lots in the vicinity that charge approximately $250 on a monthly basis. Thus, employees do have the option to drive to campus without purchasing a permit from MIT. 7% of those people without a pass or permit indicate that they primarily drive, 5% drove every day in the previous week, and 9% drove at least once. Either these people were not able to get a permit from MIT or they arrive on campus at times when on-street spaces are easy to find. As expected, 52% of people who do not participate in either the parking or transit benefits indicate that they are primarily pedestrians and 43% walked or biked every day in the previous week, while 56% walked or biked at least once in the previous week. Surprisingly, 32% indicate that they primarily take transit, and 26% always take transit. Until April 2009, people who took Amtrak or private bus services were not eligible for any benefits, such as vouchers to pay for those tickets with pre-tax and/or subsidized dollars. This is likely less than 10% of the approximately 500 people who primarily take transit, but do not purchase a transit pass through MIT.

It is hard to explain the behavior of the other people in the non-participant group. Their behavior, if anything, is less variable than other people who take transit primarily. They may not be aware of the program, or may find it too cumbersome to enroll. Looking at the awareness data, approximately 10% of the people who primarily take transit but do not purchase a pass through MIT are not aware that MIT offers subsidized passes. 30% are aware, but choose not to do so. The remaining 60% indicate that they do purchase a transit pass through MIT. The data shows some variability from month to month. For example, someone could have failed to purchase a pass in the month for which purchase data exists, but did do so in the prior and subsequent months. This month-to-month variability only accounts for approximately 50% of the remaining discrepancy. There are approximately 150 people who indicate that they purchase transit from MIT, but are not recorded as doing so. Either the data is incomplete, or people have misinterpreted or biased their answers on the survey

With the previous caveats in mind, assuming that the answers given on the survey are correct, the implication is that a full "mandatory" Universal Access Pass program with an opt-out possibility will immediately enroll an additional 200-400 people, even without a price change. At an average subsidy of $540 per year, bringing these people into the existing subsidy will cost MIT $108,000-216,000 per year, and provide additional revenue to the MBTA. That said, if these calculations are correct, these are people who should be receiving the subsidy today. That extra cost would also be incurred if MIT were to run a more widespread information campaign.

In summary, people with monthly permits show less variability in their behavior than those people who have more flexible benefits, such as the Occasional Parking Permit and transit pass combination. Policies that encourage flexibility result in less auto usage and more transit usage. Despite the economic incentives to use only the mode to which the benefit applies, 11-33% of people—depending on the benefit—use other modes at least once per week. This may be indicative of a latent demand for more flexibility. The goal is to constrain this flexibility so that it has an environmental bias, for example by requiring all parkers to have a transit pass, rather than vice versa.

6.3.2 The Effect of Transportation Subsidies on Transit Usage

This thesis has thus far assumed that employer transportation subsidies change behavior. This section examines the evidence for this hypothesis using the MIT survey data. This analysis permits estimates for the elasticity of transit demand with respect to price for a number of definitions of demand, including demand for passes, demand for trips, and demand for commute trips only.[8] These findings have implications for the benefits for transit agencies from programs that result in lower monthly pass costs for employees.

The comparison of pass purchases and transit usage between staff who are eligible to receive benefits from MIT, and those who are not eligible is a naturally occurring experimental design. However, there are some differences between the group eligible for benefits, and those who are not eligible. For a comparison between these groups to be significant, the underlying composition must be similar. A *post*

[8] This assumes that this behavior is purely market responsive to price. However, the availability of parking, particularly convenient parking, is limited. Access is effectively regulated or managed by department. The transit pass subsidy can be viewed as a mitigation of the dissatisfaction anticipated to be caused by this constraint on convenient parking.

hoc experiment requires that the controls that would be in place with a designed experiment are *de facto* in effect. These comparisons are made using variables considered to be endogenous. If these groups are similar in composition within these endogenous variables, then the significant difference between them is whether they receive a transportation subsidy from MIT. The reason for the difference in their commute behavior is a result of MIT's transportation subsidies. We describe the methodology for controlling for those differences in more depth in Appendix 2. In presenting the results throughout this section we present both the results that correct for this expected bias, and the uncorrected results.

Based on the differences in age and location between samples, the expectation was that the control group would have 4% fewer pedestrians, but Table 6-12 shows that it has 2% more; 1% fewer transit users, when it in fact has approximately 6% fewer; and 1% more people ridesharing, when it in fact has 1% fewer. The difference between drive alone mode share for the control and experimental groups is almost exactly the predicted 2.5%. That is to say, there seems to be some indication that transit pass subsidies do in fact effect transit pass purchases. Because MIT offers parking to these employees on a monthly basis for the same price as benefits-eligible employees, we can derive elasticity measures for transit directly. A pure point elasticity of the demand for transit with respect to price, a 50% subsidy or decrease in the pass cost for those with benefits, is -0.30 without taking into account the age and location differences in the groups, or -0.25 with age and location differences.[9] Throughout the remainder of this section we present only the elasticities that do not take into account these differences. Elasticities based on these differences are 10-15% lower, depending on the measure.

Table 6-12. Primary Commute Method By Benefits Eligibility, Employees, 2008

	Eligible (Experiment)	Ineligible (Control)
Drive alone the entire way	15.3%	17.2%
Drive alone, then take public transportation	1.8%	2.9%
Walk, then take public transportation	40.0%	31.1%
Share ride/dropped off, then take public transportation	1.2%	2.4%
Bicycle and take public transportation	2.6%	3.3%
Ride in a private car with another person	4.0%	1.9%
Ride in a private car with 2-6 commuters	0.3%	1.0%
Ride in a vanpool or private shuttle	1.2%	1.4%
Dropped off at work	0.2%	0.0%
Bicycle	15.5%	15.3%
Walk	16.8%	19.1%
Other	1.2%	4.3%

[9] Calculated by dividing the percent change in public transportation mode share between the experimental and control groups by the difference in costs (50%) for a LinkPass between those groups.

The survey question that asked whether the respondent had purchased an MBTA Monthly Pass in the last month allows a direct look at pass purchasing behavior, as opposed to the derivation of the elasticity with respect to commute behavior, derived above. In the control group 43% purchased a monthly pass, vs. 56% in the experimental group. This is equivalent to an elasticity of demand for passes with respect to price of -0.60.

Looking at the variability between days evident in Table 6-13, the decrease in pedestrians for the experimental group is particularly pronounced, as is the decrease in people who have ridesharing as part of their mode bundle, while the increase in transit users is slightly less evident. The calculated point elasticity of everyday transit demand is -0.22 and for occasional transit usage is -0.26. Comparing average commute trips per week on transit, the experimental group averages 2.2 trips per week, vs. the control group at 1.9 (-0.29 elasticity of demand).

Table 6-13. Bundling By Benefits Eligibility, Non-Faculty Academic Employees Who Are On Campus More Than 30 Hours Per Week, 2008

	Eligible (Experiment)	Ineligible (Control)
Always Drive	12.0%	14.2%
Ever Drive	19.7%	24.5%
Always Transit	36.5%	32.8%
Ever Transit	53.7%	47.5%
Always Rideshare	4.2%	3.4%
Ever Rideshare	10.4%	6.9%
Always Pedestrian	24.2%	27.9%
Ever Pedestrian	36.2%	39.7%

These elasticity estimates are well within the margin of this chapter's previous finding on primary mode, but significantly lower than the findings for pass purchases. This thesis takes the position that these are not contradictory findings, but rather represent different levels of responsiveness to price for different types of demand. Pass purchases directly measures the product that is being discounted, rather than derived demand based on that product. The expectation is therefore that it will be higher than the elasticity of demand for trips. Pass purchases include (1) the expectation of change in behavior on the behalf of the purchaser, and (2) the convenience of having an automatically refilled pass, for commuting and non-commute uses, rather than the use of the transit system for the commute trip only, and the added advantage of purchasing that pass with pre-tax dollars for benefits-eligible employees.

Examining total linked trips on the MBTA system[10] by the experimental and control groups, there are 5.89 trips on average for the control group, and 7.00 trips for the experimental group, for a point elasticity of demand of transit trips with respect to

[10] The methodology behind this calculation is examined in Chapter 7.

pass price of -0.38. For the previous week of trips, the elasticity of demand with respect to pass price is -0.40. Table 6-14 shows that the highest elasticity is for passes, followed by all trips, followed by commute trips on an everyday or occasional basis, and finally by commute trips for everyday travel on transit. Given the direct subsidy to passes only, this order of demand responsiveness is as expected. Furthermore, it points to the conclusion that the employers' direct subsidy of passes is significantly revenue positive for the MBTA. The number of people with transit passes given a 50% subsidy increases 30% from what it would without the subsidy (-0.60 elasticity). The number of transit trips only increases 20% (-0.40 elasticity), and the number of transit commute trips on transit during the peak only increases between 11% and 13% (-0.22 and -0.26 elasticity for everyday and occasional mode bundles). Not only are revenues higher, but the need for increased service is proportionally lower than the revenue increase.

Table 6-14. Elasticities Of Transit Demand With Respect To Price

Measure with respect to pass price	Elasticity Range
Demand for Passes	-0.56 to -0.60
Demand for Usage	-0.25 to -0.30
Demand for Every Day Commute Usage	-0.18 to -0.22
Demand for Occasional Commute Usage	-0.22 to -0.26
Demand for Total Commute Trips	-0.25 to -0.29
Demand for Total Linked Trips	-0.34 to -0.40

This translates to real money for the MBTA. The average monthly price that MIT pays the MBTA is $90 per transit pass holder, including Commuter Rail. Applying the elasticity measures in Table 6-14 to MIT's situation, there are 700 additional MBTA passholders at MIT because of the subsidy. By simple multiplication, this means $760k annually in gross additional revenue for the MBTA because of the MIT policy of subsidizing transit passes. Based on an elasticity of demand for trips with respect to the pass price of -0.40, and an average monthly per-use fare value of $102[11], the cash fare value of those trips is $550k. In other words, via MIT's in kind subsidy of monthly passes, the MBTA receives approximately 24% in revenue via pass sales above what they would receive for a cash subsidy of fares or passes by MIT.

The current situation is clearly advantageous to the MBTA. It also implies that any changes to the way passes are paid for has large implications not just for MIT, but for the MBTA. In a Pay-per-ride regime, MIT is no longer responsible for paying for monthly passes, but instead pays the MBTA only for each fare used. In other words, the MBTA no longer receives the additional revenue for passes due to the subsidy, but only for actual fares used. This decrease is mitigated by the earlier finding in this chapter of an additional population who use transit, but do not purchase a pass through MIT. A pay-per-ride regime that is opt-out thus includes both positive and negative revenue implications for the MBTA.

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[11] 40 one-way trips per month on the Commuter Rail or using a LinkPass

To project revenue loss and gain from changing to this regime is not as simple as using an elasticity-based measure. It requires examining the average amount of travel for each person, including for those people who travel more than the equivalent pass price in per-use fares. Chapter 3 showed that in London pure pay-per-ride actually results in a 3% increase in revenue for the system as a whole vs. monthly passes. A similar analysis for MIT's MBTA ridership requires disaggregate analysis of the distribution of weekly trips. The Mobility Pass increases the reach of MIT's subsidy, so that people who would not normally partake in it are now subsidized by default. The calculation for whether the Mobility Pass is revenue positive for the MBTA requires comparing the increase in ridership from this increased reach to any revenue loss from moving to a pay-per-ride system. This topic is pursued in Chapter 7.

6.4 Demographics: Age And Accessibility Matter

The expectation is that employees who drive to MIT do so because of preference, and that these preferences are ingrained. The inference behind this assumption is that people who are older, have not moved for along time, or are faculty and administrative staff have activity patterns for which car travel is the most optimal mode. While these expectations are, to some extent, true, they only tell a portion of the story. This section demonstrates that there is a great deal of variability in mode choice within demographic groups. If the goal is to create policies that encourage these employees to travel by more sustainable modes, that their cohorts are already doing so is heartening.

Even more encouraging is the examination of the demographics and mode choice of those people who live within 1/10 and ¼ of a mile of another employee who purchases a transit pass from MIT.[12] These are areas that are by definition transit accessible. Distance between an employee with a Commuter Permit and an employee who takes transit does not significantly change the percentage of employees who ever drive, but does make it less likely that they drive every day.

6.4.1 Age as proxy for lifecycle outweighs other factors

One commonly held perception is that mode choice is determined by the person's status; people with lower status jobs, and less income, are more likely to use alternatives to driving alone. For MIT, direct indicators of status are not available, so job type is used as a proxy. If position is a proxy for salary, Table 6-15 shows that there is a slight correlation between income and mode share, but it is smaller than expected. Non-Faculty Academic Staff, mostly researchers and lecturers, have significantly lower drive mode shares than other employees. They also have a higher pedestrian mode share; this may be more a measure of choice, than necessity. That is, academic staff place more value on living in closer proximity to MIT than do non-academic staff. Pedestrian mode share for faculty, academic, and research staff is similar, even as drive alone mode share for faculty is much higher. A full 38% of academic staff walked or biked to MIT at least once during the week

[12] Both measures are used as a check of the sensitivity to distance.

studied. The percentage of employees who rideshare either regularly or occasionally is consistent across employee type, with the exception of medical staff, who rideshare less than others, likely due to the unpredictability of their schedules.

Table 6-15. Bundled Mode Share, Employees, Weighted, 2008

	Faculty	Staff: Other Acad.	Staff: Admin	Staff: Support	Staff: Spons. Rsrch	Staff: Medical	Total
Transit	13%	35%	29%	39%	34%	28%	31%
Drive	38%	13%	37%	24%	22%	46%	27%
Pedestrian	15%	25%	5%	8%	14%	7%	13%
Drive + Transit	6%	4%	7%	6%	7%	6%	6%
Rideshare	5%	4%	7%	7%	6%	1%	6%
Transit + Pedestrian	4%	7%	2%	4%	5%	0%	4%
Other or Not on Campus	7%	3%	3%	4%	4%	6%	4%
Drive + Rideshare	3%	1%	4%	2%	3%	4%	3%
Transit + Rideshare	1%	3%	2%	3%	2%	0%	2%
Drive + Pedestrian	4%	2%	1%	1%	2%	2%	2%
Rideshare + Pedestrian	2%	2%	0%	1%	1%	0%	1%
Drive + Transit + Pedestrian	0%	0%	1%	0%	1%	0%	0%
Drive + Transit + Rideshare	1%	0%	0%	0%	0%	0%	0%
Transit + Rideshare + Pedestrian	0%	0%	0%	0%	1%	0%	0%
Drive + Rideshare + Pedestrian	1%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

Prior research (Rosenbloom & Burns, 1994) suggests that women have less flexibility in mode choice than men do. This can be seen as proxy for the activity patterns associated with household tasks, including childcare. While there are no direct indicators of household size, there does seem to be some significant variations in bundling behavior by gender. Table 6-16 shows that men are more likely to be pedestrians, and less likely to rideshare, both on a regular basis, and as part of bundle of other modes. 27% of men including walking or biking as part of their commute, vs. 15% of women. Only 10% of men ever rideshare, as opposed to 16% of women.[13] There are few differences between transit usage and driving by gender, although women are slightly more likely to include both in their choice set. Women express the same amount of variance in their day-to-day mode choice as men. 77% of women use the same mode to commute each day, while 76% of men do so. There are no differences by gender in overall bundling behavior, contrary to the expectations of prior research.

[13] It may be the case that women are less likely to get use of the car than men in households which share a single car.

Table 6-16. Bundling Behavior By Gender, Employees, Weighted, 2008

	Female	Male
Other	48%	52%
Pedestrian	33%	67%
Rideshare	65%	35%
Rideshare + Pedestrian	43%	57%
Transit	53%	47%
Transit + Pedestrian	40%	60%
Transit + Rideshare	60%	40%
Transit + Rideshare + Pedestrian	63%	37%
Drive	51%	49%
Drive + Rideshare	30%	70%
Drive + Pedestrian	67%	33%
Drive + Rideshare + Pedestrian	18%	82%
Drive + Transit	53%	47%
Drive + Transit + Pedestrian	30%	70%
Drive + Transit + Rideshare	61%	39%
Total	50%	50%

One measurement of how entrenched these patterns are for employees is car ownership. Chapter 2 established that car ownership is a longer-term decision than daily mode choice. The expectation is therefore that higher car ownership is a proxy for the extent to which driving is a part of their lifestyle, and the opposite for transit users and people who walk. Car ownership is a proxy for the entire set of activity patterns beyond the commute. Not surprisingly, per Table 6-17, people without cars rarely use them to commute. As car ownership increases, the percentage of people who always and occasionally commute via the automobile also increases, up to 2 cars, after which drive commute mode share is essentially flat.[14]

Table 6-17. Bundling Behavior By Cars Owned In HH, Employees, Weighted, 2008

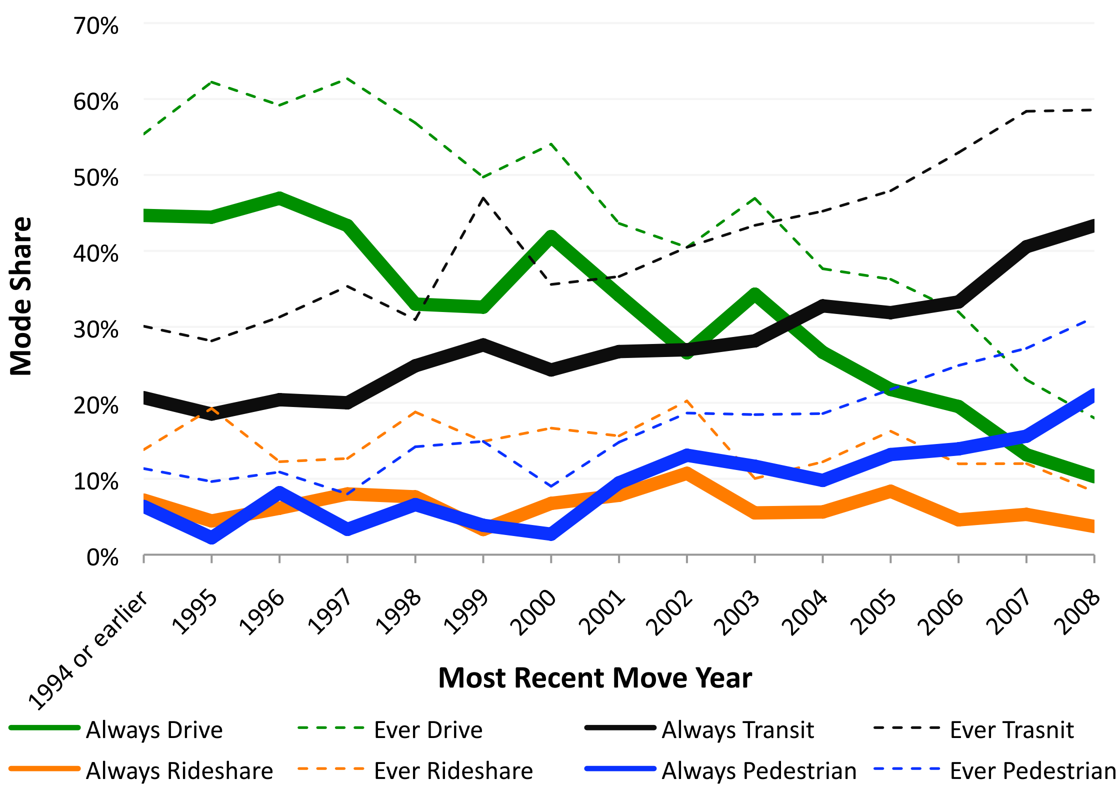
	Cars in HH						
	0	1	2	3	4	5+	Total
Always Drive	1%	18%	43%	46%	47%	29%	27%
Ever Drive	1%	30%	59%	58%	61%	47%	39%
Always Transit	50%	35%	21%	21%	20%	39%	31%
Ever Transit	64%	51%	33%	32%	28%	49%	45%
Always Rideshare	1%	6%	7%	7%	6%	6%	6%
Ever Rideshare	4%	14%	14%	15%	18%	18%	13%
Always Pedestrian	31%	14%	4%	5%	4%	4%	12%
Ever Pedestrian	45%	25%	9%	8%	7%	8%	20%

[14] The change in 5+ cars is likely due to non-family households. There were fewer than 50 respondents who indicated they had 5+ cars.

When someone has two cars they tend to have enough for each driving member of the household to use at any given time. They can therefore make a choice unconstrained by the other member's activities. The purchase of a second automobile is indicative of an auto-oriented activity pattern outside of the journey to work. Causation, of course, need not run in this direction. It might be the case that people who wish to, or must drive, have more cars in order to satisfy this need. This direction of causation is supported by the fact that so few people who have 2 cars ever bicycle or walk to work. Working against this second explanation are the 20% of people with 2 or more cars use transit to commute. Ridesharing on both an every day and an occasional basis is independent of car ownership, once a car exists in the household. The implication is that ridesharing is a choice, not a necessity.

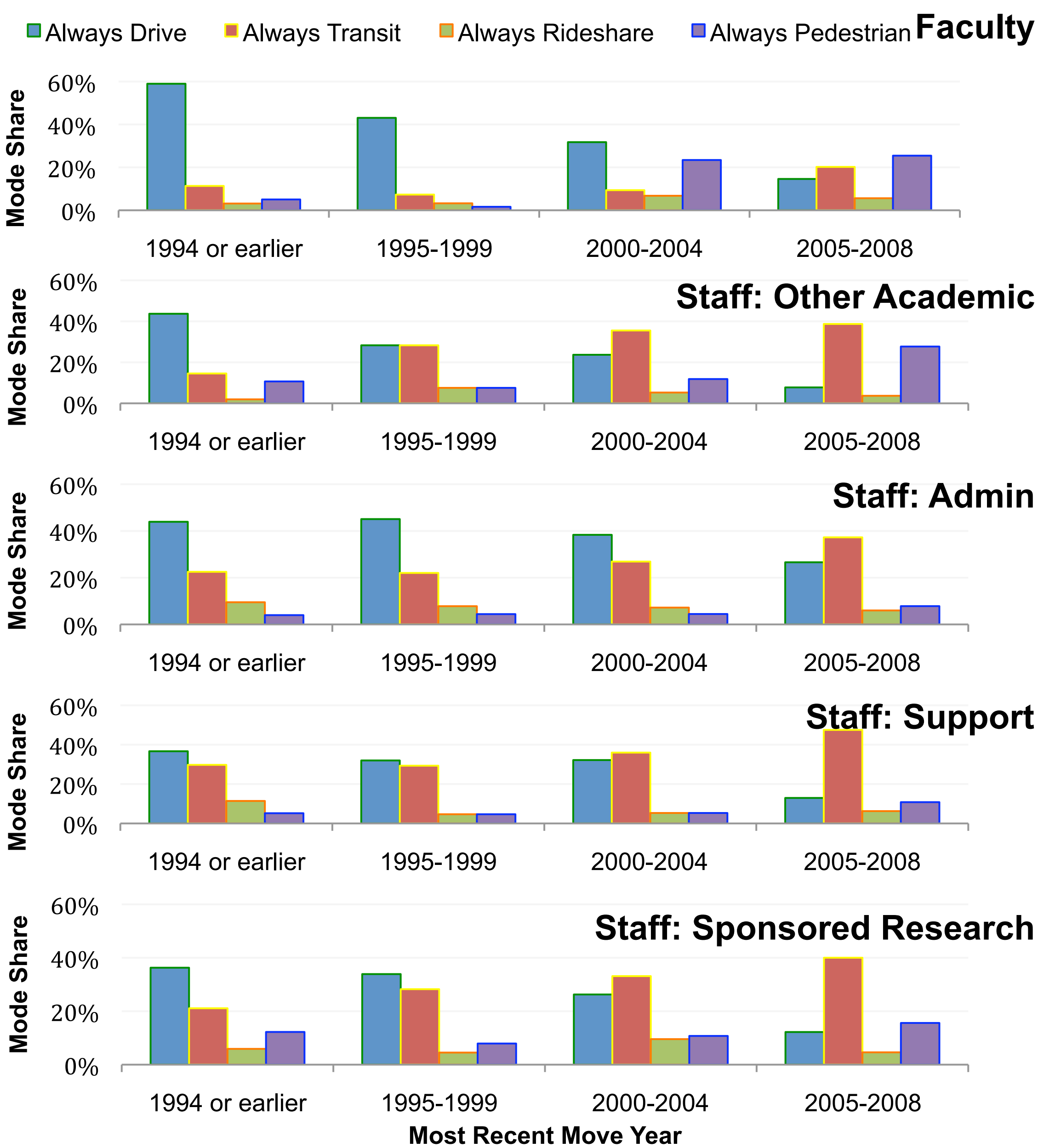
The most recent year someone moved is another proxy for how fixed a person's activity patterns are. The expectation is that the longer since a person last moved, the more likely they are to have established their commuting patterns many years ago. Figure 6-4 shows that a more stable residential location, as a proxy for lifecycle stage, is correlated with a higher mode share for SOV travel, and a lower propensity for day-to-day variability in mode choice. Both congestion and awareness of the environmental impacts of driving have increased over time. This is likely to effect location choice for people who have moved more recently toward areas that are non-SOV commute friendly . Additionally, younger people move more, and thus are more likely to be in the cohort of people who have moved recently.

Figure 6-4. Mode Share By Most Recent Year Moved, Employees, Weighted, 2008



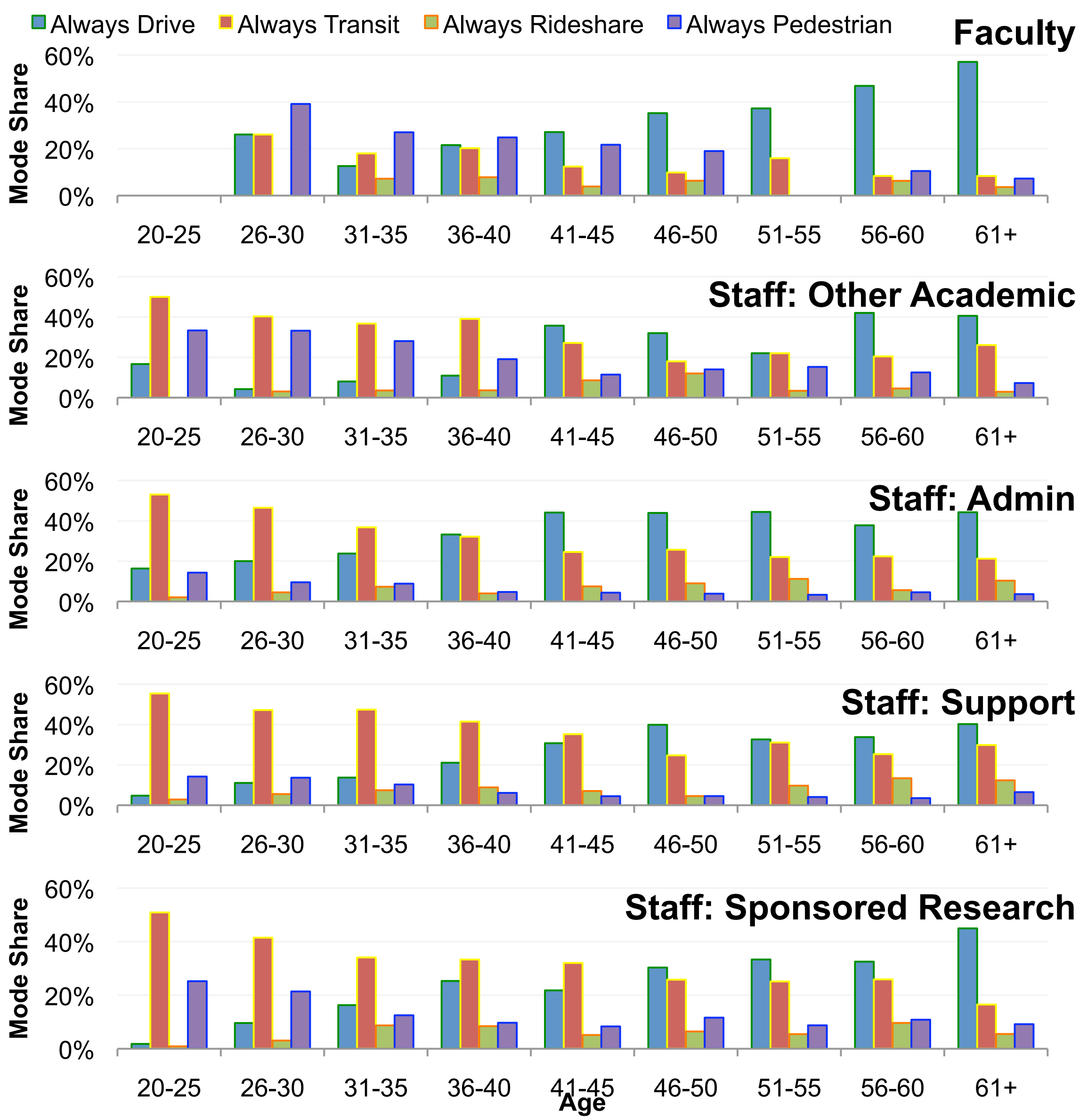
If the cohort effect is evident, than the prevalence of the younger non-Faculty Academic Staff in the population explains the propensity for more recent movers to use transit. However, for each type of employee in Figure 6-5, drive mode share decreases and transit mode share increases as the move year becomes more recent. Those non-Faculty Academic Staff who have moved in the last 4 years look remarkably like faculty in their transit and pedestrian mode shares.   Figure 6-6, confirms one possible explanation of this pattern is the age of the employee, as a proxy for their lifecycle stage. It may also be a manifestation of the process of re-optimizing location, car ownership, and mode choices.

Figure 6-5. Mode Share By Type Of Employee, By Move Year



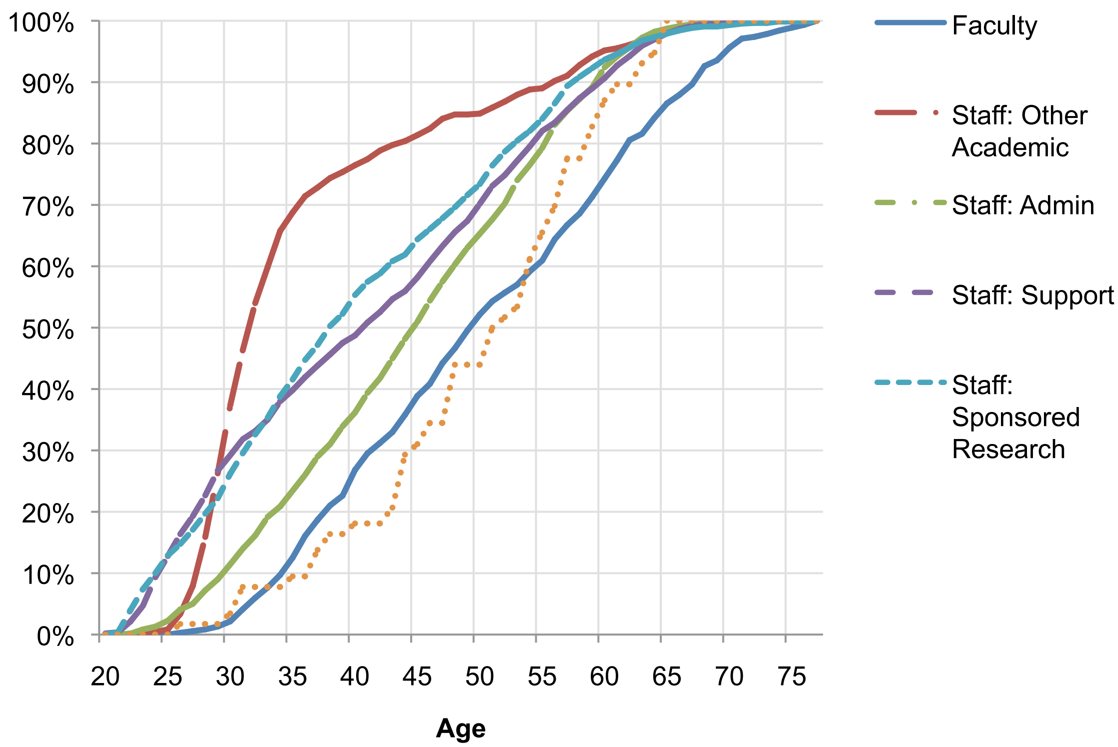
As can be seen in Figure 6-6, the pattern of increasing use of the auto, and decreased use of transit, biking, and walking is prevalent across all types of employees. While Faculty who are 51 or older and Administrative Staff 41 or older are auto-oriented, it is not the case for younger Faculty and staff. If this was entirely explained by activity patterns surrounding childcare, the transition from transit to driving would take place closer to 30 or 35. Instead, drive mode share starts growing across job types at age 30, and does not level off until 45 or 50, depending on the type of employee. The implication is that there may be more room for growth in transit mode share across all employee types. Activity patterns do not predetermine mode choice.

Figure 6-6. Mode Share Of Selected Employee Types, By Age Of Employee



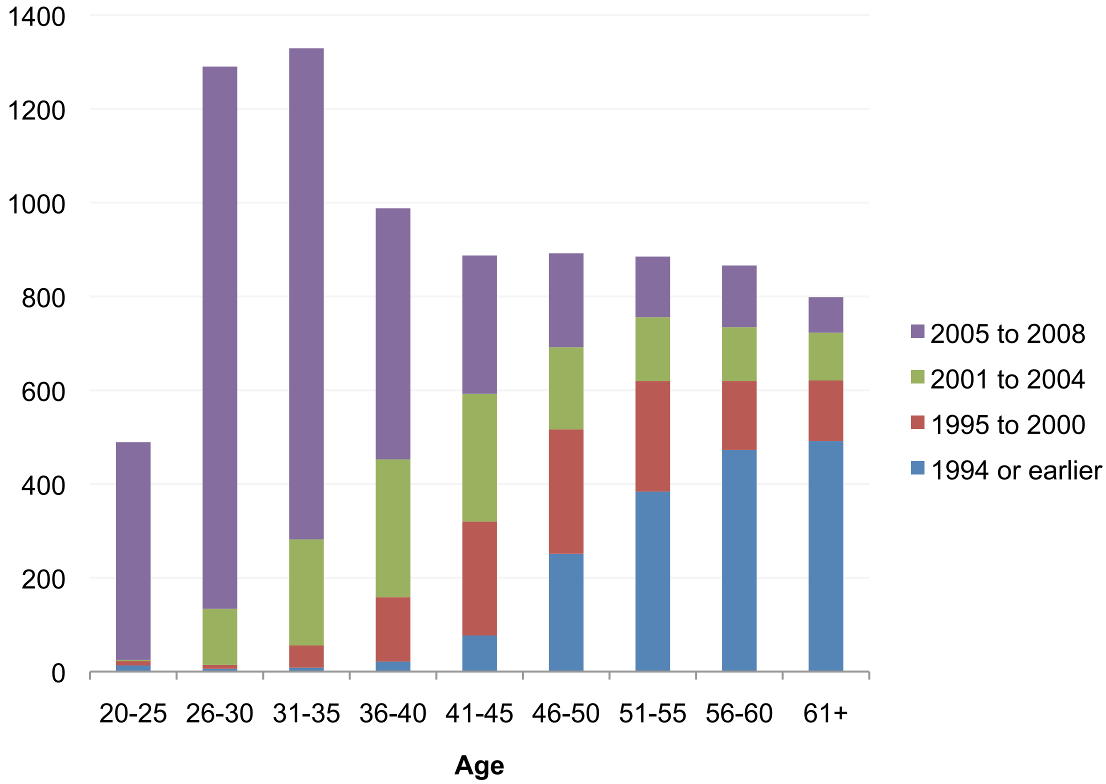
The relative proportion of employees in the population leads to the misperception that mode share is determined by the type of employee. Age is a significantly more powerful effect than employee type. As shown in Figure 6-7, 70% of non-Faculty Academic Staff are under 35, but less than 15% of Faculty are. It is easy to perceive that faculty drive to MIT each day in disproportion to their representation in the population. However, Faculty who are 40 or younger drive to MIT the same or less than other groups, with the exception of Administrative Staff. Faculty over 50 do not drive disproportionately for their age group. The proportion of Faculty over 50 creates the misperception about deterministic mode choice.

Figure 6-7. Cumulative Distribution Function Of Age By Employee Type



Age also determines when an employee moved most recently. Per Figure 6-8, most of those people who last moved more than 15 years ago are over 46, and most of those who last moved in the last 4 years are 35 or under. As people age they move less. This supports the hypothesis of more settled activity patterns for the older cohort. This is still an encouraging result if the goal is to change behavior. When people move, the literature shows that they re-evaluate the attributes of the their transportation choices. It is a seducible moment. Up until 35 people move quite often. However, almost 2/3 of the people who are 46-50 and 25% of those over 56 have moved in the last 8 years. If the best opportunity for mode switch is when there is also a change in location, then there is opportunity for mode switch across all age groups. The implication is that the actual effects of mode switch will be greater than the models—which are based on short run decisions—predict.

Figure 6-8. Distribution Of Employees By Age And Move Year



As seen in both Figure 6-9 and Figure 6-10, those people who have moved recently have moved closer to campus. This effect only exists for people who have moved in the last 4 years. Those people who moved 5 years ago are equally likely to have located within 4 miles of MIT than those people who moved 15 or more years ago. However, those people who moved 10 or more years ago are 1.5-2 times as likely to have moved more than 7 miles out than those people who moved in the last 8 years, and 3-4 times as likely as those people who moved in the last 4. The implication is that people are no longer locating as far from MIT as they once did. Because of the changing circumstances (more congestion, increased environmental awareness, gasoline prices, etc.) over the last 10 years, this may be indicative of a newly manifested preference for living closer to MIT. It may also be a manifestation of the tendency to commit to a long-term location decision once someone has moved away from the CBD.

Figure 6-9. Most Recent Year Moved By Distance From MIT

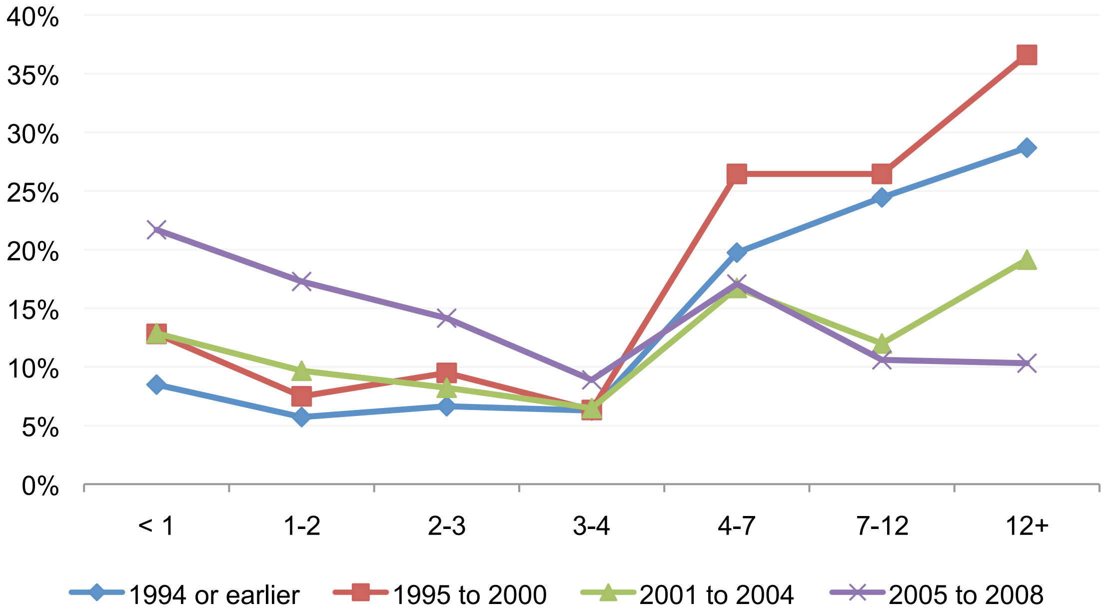
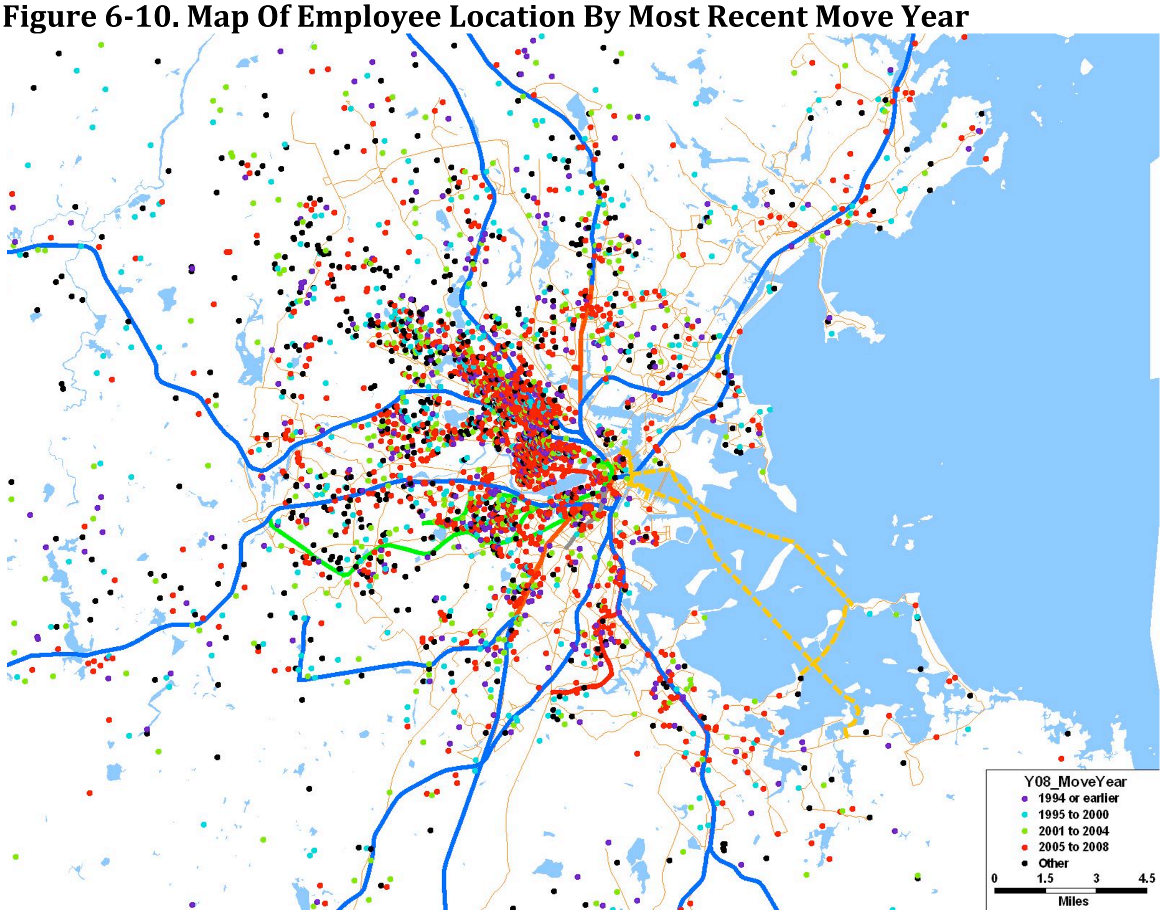


Figure 6-10. Map Of Employee Location By Most Recent Move Year



6.4.2 Accessibility Effects

Using a model of the Boston transit network, and the geocoded home locations, each employee was tagged with his or her distance to the nearest bus stop, subway, light rail, or commuter rail station. Figure 6-11 shows that as distance from a bus stop increases, everyday transit mode share and walking and biking mode share both decrease. Figure 6-12 indicates that there is also a small effect on transit and pedestrian mode share for those people who do not use the mode every day. That is, access affects both regular and variable behavior. If the goal is behavioral change, this points to targeting those people who do have good access to transit, and are currently using it occasionally or not at all.

Figure 6-11. Use Of Mode Everyday By Distance To Nearest Bus Stop

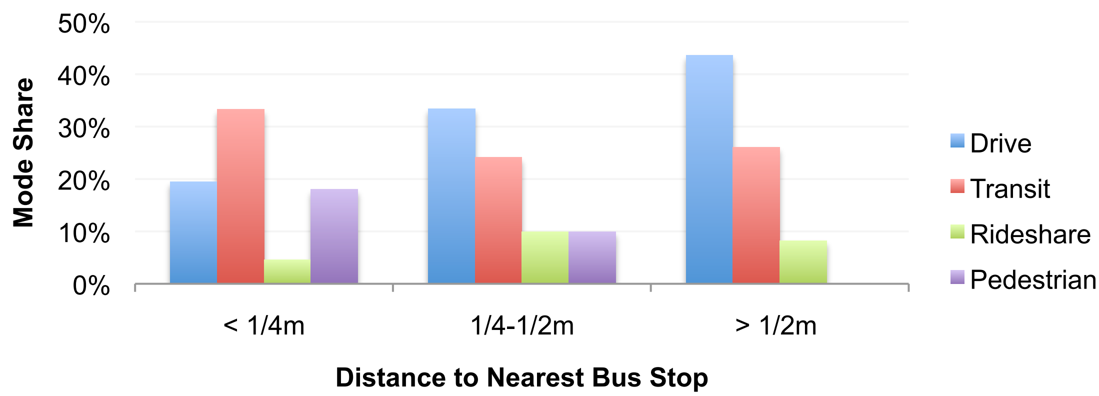


Figure 6-12. Use Of Mode Less Than Everyday By Distance To Bus Stop

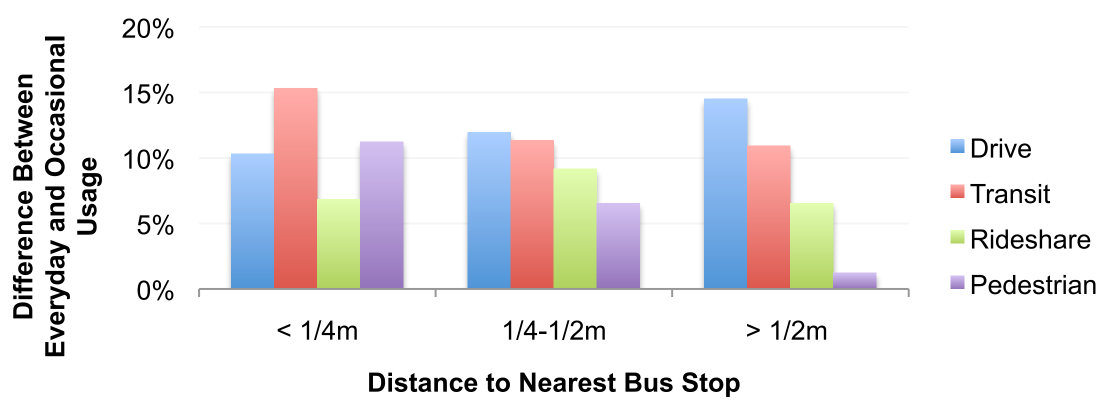


Figure 6-13 and Figure 6-14 indicate that there are similar effects for subway and light rail, with the most marked increase in driving for those people who live more than a mile from the nearest subway station. Multimodalism that includes transit is more prevalent when people live closer to a subway station. People who live in proximity to transit use it, and combine that usage with other modes when their day's activity pattern is better suited to walking or driving.

Figure 6-13. Use Of Mode Every Day By Distance To Nearest Subway Stop

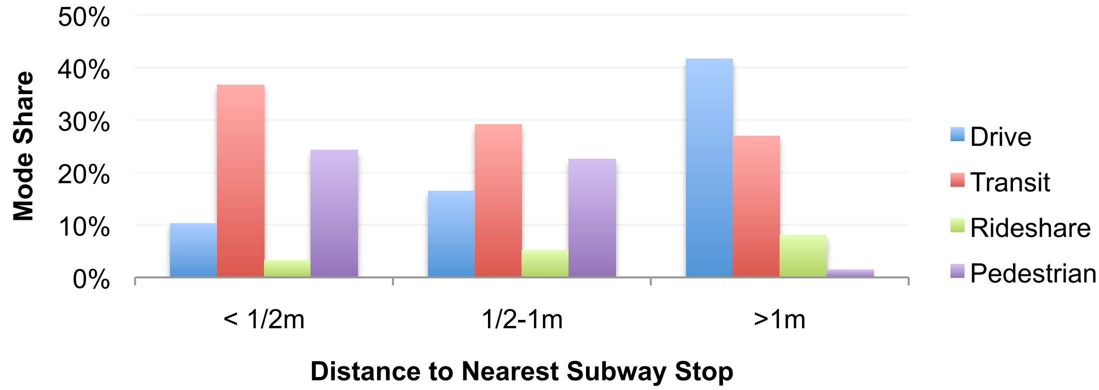
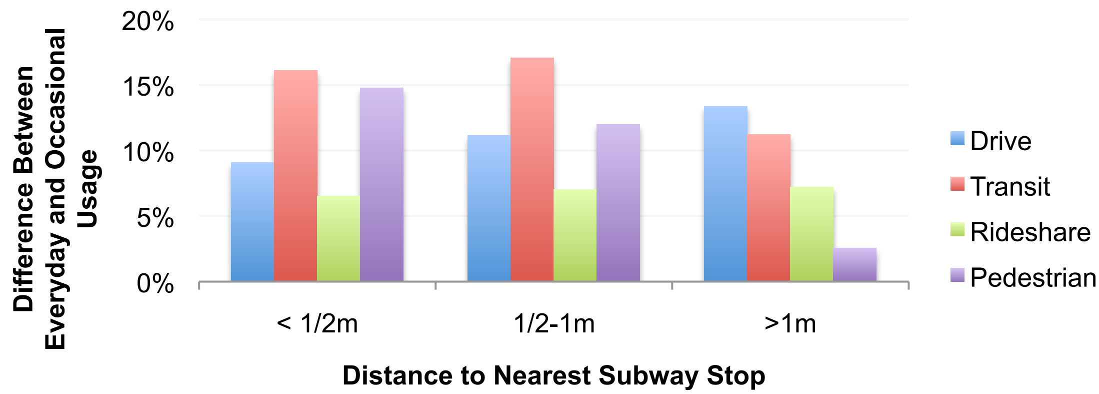


Figure 6-14. Use Of Mode Less Than Everyday By Distance To Nearest Subway Stop



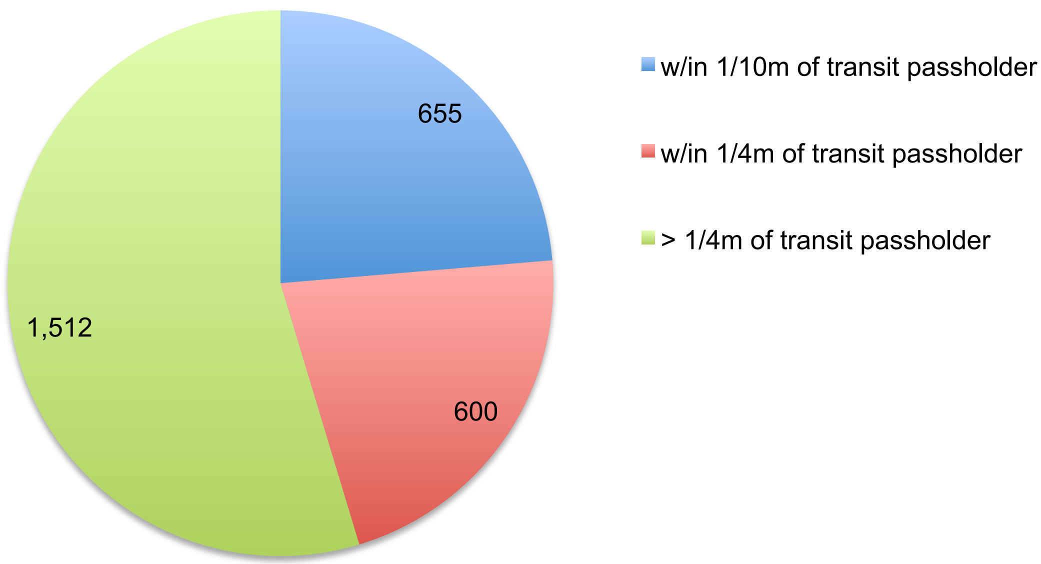
6.4.3 AFFECT OF NEAREST TRANSIT NEIGHBOR

One opportunity for changing behavior lies in what ones neighbors are doing. They have similar access to transit—accounting for pedestrian and driving conditions—and are relatively similar demographically. If the person down the block is able to take transit to get to MIT, they probably can too. Those people who currently have a monthly parking permit, and live nearby someone who has a transit pass—whether alone or in combination with an Occasional Parking Permit—are likely candidates to be able to change their commute patterns. This is especially true if a reduction of expensive leased parking in the Kendall Square area results in a tightening of parking availability.

Figure 6-15 shows that fully 24% of people who have monthly parking permits are within 2 blocks of someone who has a monthly transit pass. An additional 22% live within a quarter mile of a transit pass holder. Travel by transit would not make these groups significantly worse off overall. There is no access barrier for this group. If this group did take 1 roundtrip per week on transit randomly distributed on each day of the week, it would reduce parking demand by 125 spaces monthly. Assume that there will be some overlap in when they take transit, so MIT could save 75-100 spaces without worrying about whether demand will be too high some days.

Those 75-100 spaces cost the equivalent of $12 per day for MIT to lease. In other words, MIT could give an incentive of $10 per day and break even, just targeting this group. Transit is not the only way to reduce driving. The 55% of drivers who are more than ¼ mile from a transit pass holder can drive less by occasionally sharing a ride with a spouse or neighbor. These cost calculations are the basis for the analysis in Chapter 7.

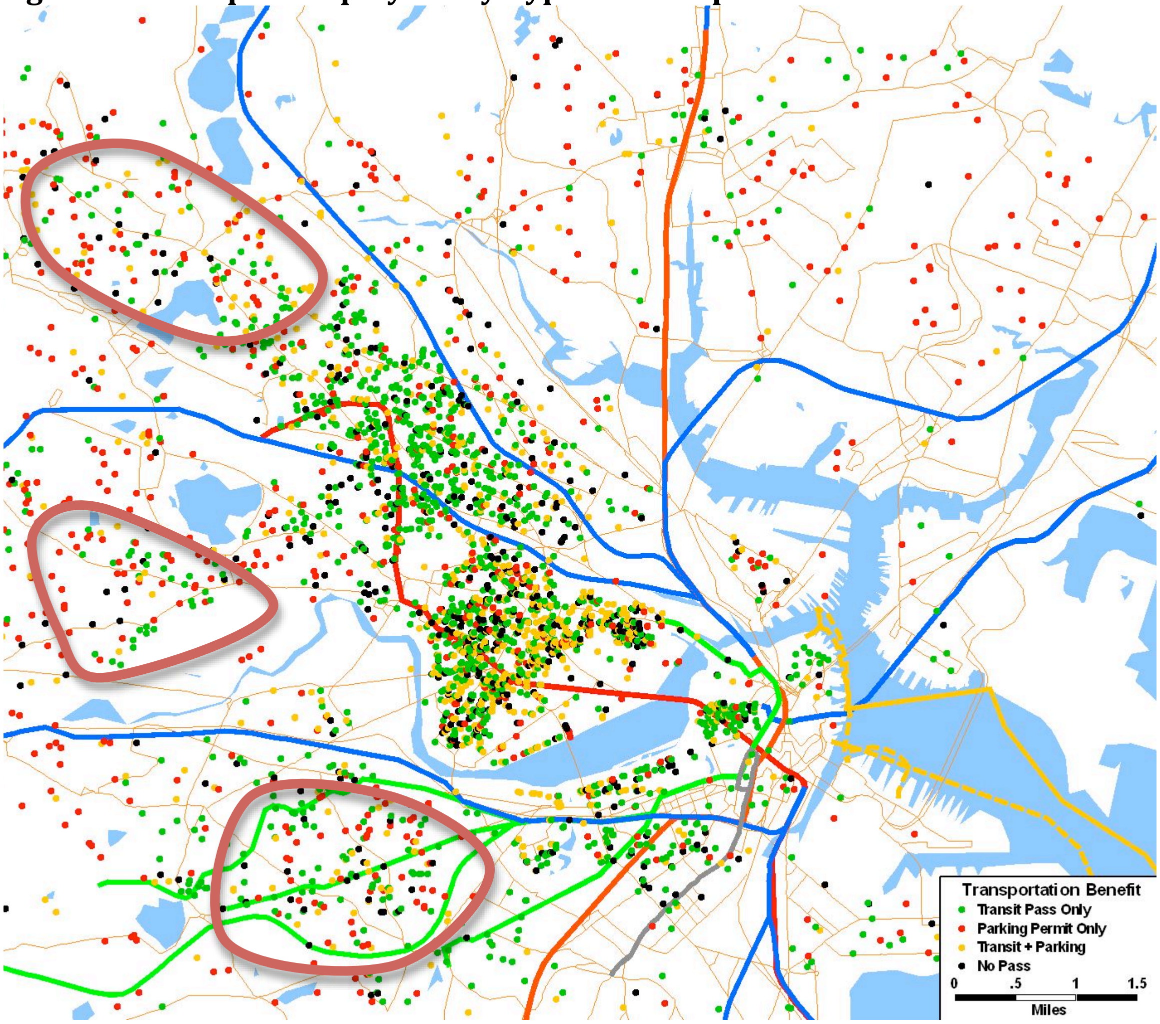
Figure 6-15. Commuter Parking Permit Holder Proximity To Neighbors With Transit Passes



* Raw numbers are less than the total number of Commuter Permitholders, because of the success rate with geocoding locations. Results were not scaled to the population, because there is no means to infer the locations of non-geocoded respondents.

In a more visual sense, Figure 6-16 illustrates those people who have an opportunity to switch modes are the ones with parking permits only (red) in proximity to those people who have a transit pass exclusively (green) or both a parking permit and a transit pass (yellow). There are opportunities all over the map, but the clearest opportunities lie in the three areas outlined above – in the proximity of the Green Line on the bottom, on the buses that travel into Harvard Square in the middle, and up by Route 2 on the top. Those people who choose to only drive to MIT in these areas are surrounded by people who have chosen to take transit.

Figure 6-16. Map Of Employees By Type Of Transportation Benefit Received



This target is appropriate not only because of access, but because of current behavior. As can be seen in Figure 6-17, those people who have monthly parking permits, but are near someone who takes transit, do take transit more frequently in combination with other modes. They are also less committed to driving every day. Almost 20% fewer people with monthly parking permits drive everyday if they are within 1/10 of a mile of someone with a transit pass than if they are more than ¼ of a mile from a transit neighbor.

Figure 6-17. Mode Share By Proximity To Nearest Transit Neighbor, Commuter Parking Permit Holders Only

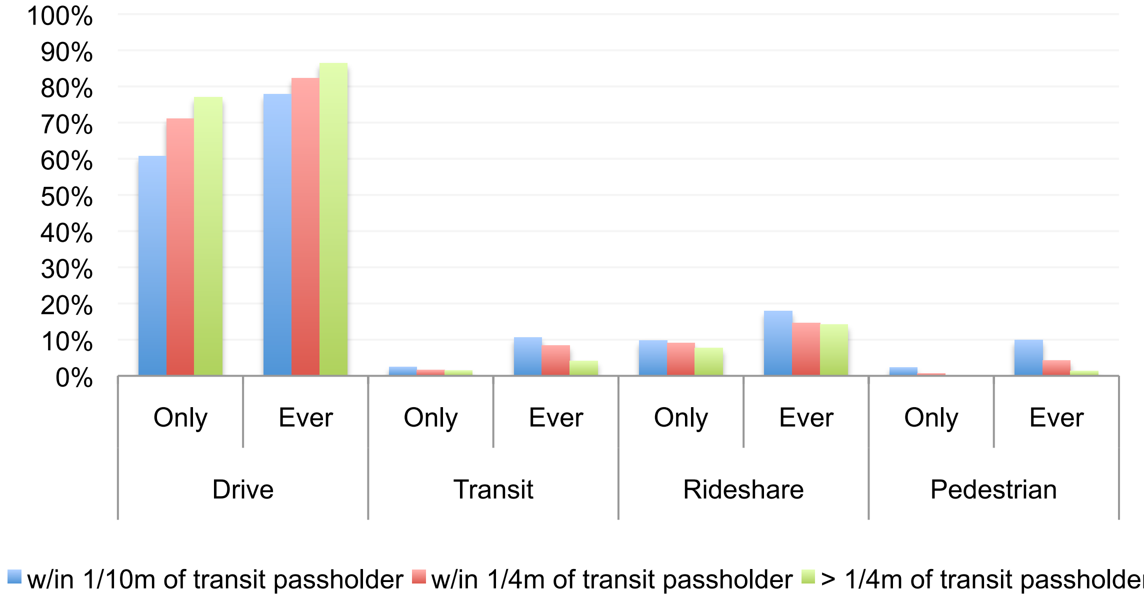
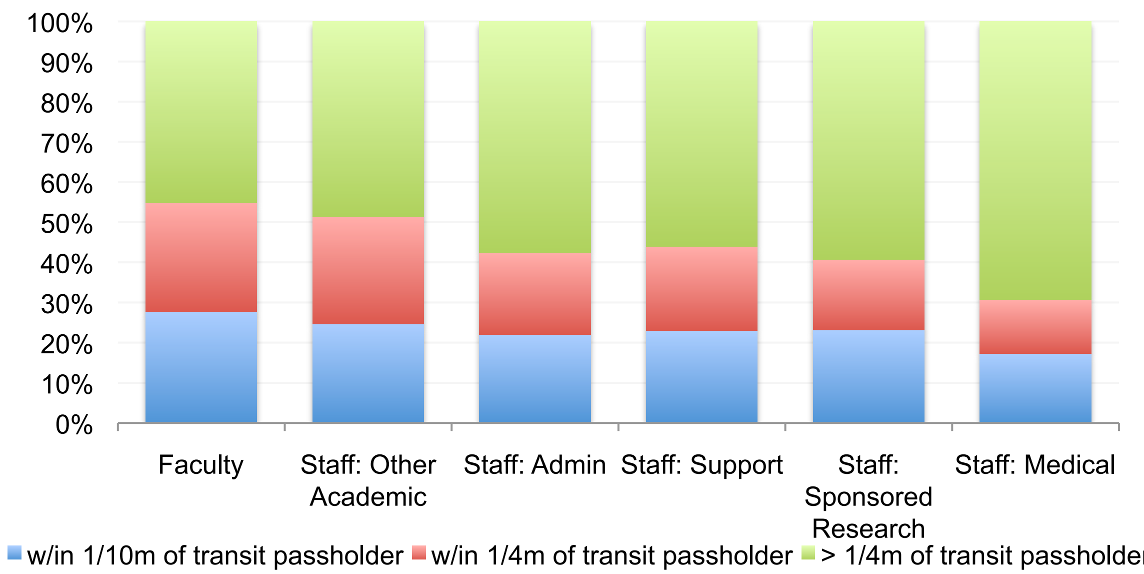


Figure 6-18 shows that the contingent of people who have the opportunity to change their behavior is not determined by the position they hold within the University. There are not significantly more choice drivers in Faculty than there are in other groups. In fact, there are fewer choice drivers in Administrative Staff than there are in other employee groups. If the opportunity is there, the question is how to impart the motive to change? Chapter 7 makes the case that this is the role of the Mobility Pass.

Figure 6-18. Employee Type Of Proximity To Nearest Transit Neighbor, Commuter Parking Permit Holders Only



6.5 Conclusions

This chapter began by showing that there are more compelling measures than daily mode share that reveal the extent of variability in the day-today mode choices of commuters to MIT. These measures indicate that 30-35% of all employees at MIT use multiple modes for their commute. More people are commuting by transit and non-motorized modes to MIT than ever before. However, very little of this change is due to disaggregate mode shift. Instead, over the last 4 years, those people who have joined MIT walk, bike, and take transit more than both those employees who have remained at MIT, and those employees who have left. This is likely due both to overall patterns outside the control of MIT, and to changes in MIT policy, although the extent to which these changes can be ascribed to either explanation is unknown.

This chapter also found that transit and parking subsidies do change the behavior of MIT employees. At a high level, the implication is that one can affect mode shift by changing employer transportation policies. Employees respond more strongly to the direct behavior being subsidized; employees at MIT are more likely to purchase transit passes because of the subsidy than they are to use them. With the current structure of payments by MIT to the MBTA this has positive revenue implications for the MBTA. Moving to regime where MIT reimburses the MBTA per ride, this additional revenue may be reduced. This chapter also finds that the additional revenue from increasing participation via an opt-out program may offset this revenue loss.

Finally, this chapter found that proxy for the employee's lifecycle stage—their age, how recently they moved, how many cars they own—were more significant than proxies for income or status, such as the type of job they hold at MIT. Even within those groups that were expected to more static in mode choice, significant events, such as moving the home location, occur. The implication is that there is more opportunity for mode switch than would otherwise be expected. Moreover, there is a significant opportunity to change behavior for those people who live within 1/10 and ¼ of a mile of someone who purchases a transit pass. Forty-six percent of the commuter population fit this description. Targeting this group may be a productive means of affecting changes in behavior to more sustainable modes of transportation.

7 ANALYSIS OF BENEFITS AND COSTS OF MOBILITY PASS PROGRAM OPTIONS

Thus far this thesis has established both the theoretical basis for multimodal behavior and evidence of its practice at MIT. It has examined the history of employer transportation subsidies, and established their effects on employee's mode choices. It has looked at the meaning of those benefits at MIT, and analyzed how the Mobility Pass, a Universal Access Pay-per-ride program, fits into the political context. This background established a rationale and a series of requirements for transportation subsidy regime change. This Chapter begins with a brief explanation of a behavioral model of trips by employees via transit, or that result in a the use of a parking space, the details of which can be found in Appendix 7. This model allows predictions of behavioral change based on policy formulations. These small behavioral adaptations when aggregated across the population have implications for the cost of transportation subsidies to MIT, to revenue and ridership for the MBTA, and to congestion for the City of Cambridge. This Chapter analyzes those policies proposed in Chapter 5, and evaluates their costs and benefits, including congestion and emissions reductions from each party's perspective. The proposed changes differ in ease of implementation, cost effectiveness, and political viability. However, they are all strictly preferred to the current subsidy regime. All of the proposed programs will decrease costs for employees and students in the short run, for MIT in the short to medium-term, and will increase ridership and therefore revenue for the MBTA, and reduce congestion on Cambridge streets.

This chapter continues with a model of how the current transportation benefits programs for parking and transit effect the financial bottom line of MIT and the MBTA. Modeling a world in which there are no transportation subsidies by MIT allows quantification of the benefits of the current programs. This is intricately tied to the attribution of cost savings and increased revenue for those institutions, and changes in congestion in the City of Cambridge. The chapter also includes a model of the costs and expected mode change under a continuation of business as usual subsidies for both growth and no-growth scenarios.

Predicting the effects of the Mobility Pass options requires a model of how people choose the type of benefits they receive. Absent any explicit data to the contrary, this model is based on a strict rational price mechanism; employees choose their benefits based on how often they "win the bet" of the bundle of monthly trips represented by a monthly transit pass or parking permit against the non-bundled alternative. The chapter than proceeds to model alternative pricing regimes for parking, including a more extensive program of pricing parking by the day as opposed to by the month. The results of these programs in combination with each other are predicted, and expected effects compared.

7.1 BEHAVIORAL MODEL

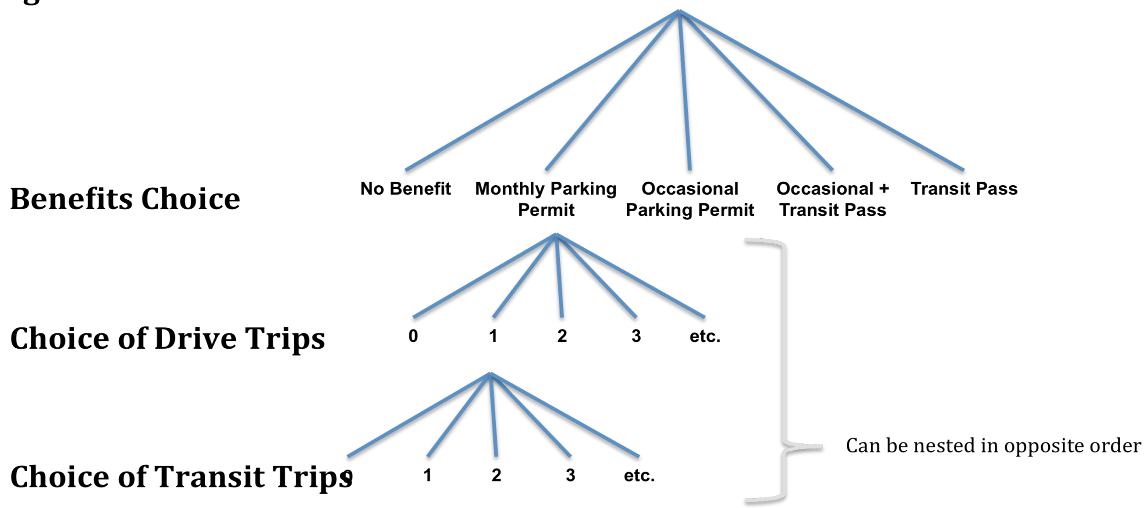
Because one of the goals of this thesis is to allow accurate predictions of the effects on employees and MIT of a change in transportation subsidy policy, any model must predict how often an employee parks at MIT, how often they take transit, and how often they walk, bike, work from home, or are dropped off. Frequency of parking establishes the cost to MIT of providing that parking, whether in leased spaces or via new construction. Transit usage, including for non-commute purposes, establishes the likelihood of purchasing a pass and thus partaking in that subsidy program, or, if a Universal Access Pay-Per-Ride program is established, the payments from MIT to the MBTA. Pedestrian and other non-subsidy commute flows are not without cost, although the cost of providing appropriate shuttle service, bike racks, showers, etc. to support this behavior is indirect.

These costs are dependent on travel behavior, which is, in turn, dependent on the benefits the employee elects to receive from MIT – whether that be a LinkPass, a Commuter Rail Pass in some Zone, a Monthly Commuter Parking Permit, an Occasional Parking Permit, some combination of the above, or no benefits election. The benefits choice is dependent on their projected behavior. In other words, each choice is endogenous to the other. Measures of both the number of trips on each mode, and the type of benefits the employee has chosen are available. However, these data are conditional on the choice in the other. This thesis only has insight in one direction: the available data is how many trips someone has taken, conditional on the type of benefit they received.

An ideal model, the structure of which is shown in Figure 7-1, takes as its dependent variable the number of trips by each mode, conditioned on the type of subsidy the employee elects. Unfortunately, with this model, the attributes of those trips—specifically the cost of driving or taking transit to MIT—are dependent on the dependent variable. With a monthly parking permit the monthly costs of driving to MIT are $65.50, and the daily costs are just the cost of gas and depreciation.[15] With an Occasional Permit, the costs are instead $4 per month, plus $4 per day, plus the costs of gas and depreciation. For transit there are similar issues between the monthly pass and the daily trip. The assumption of uncorrelated error terms that the logit model requires no longer holds. (Ben-Akiva & Lerman, 1985)

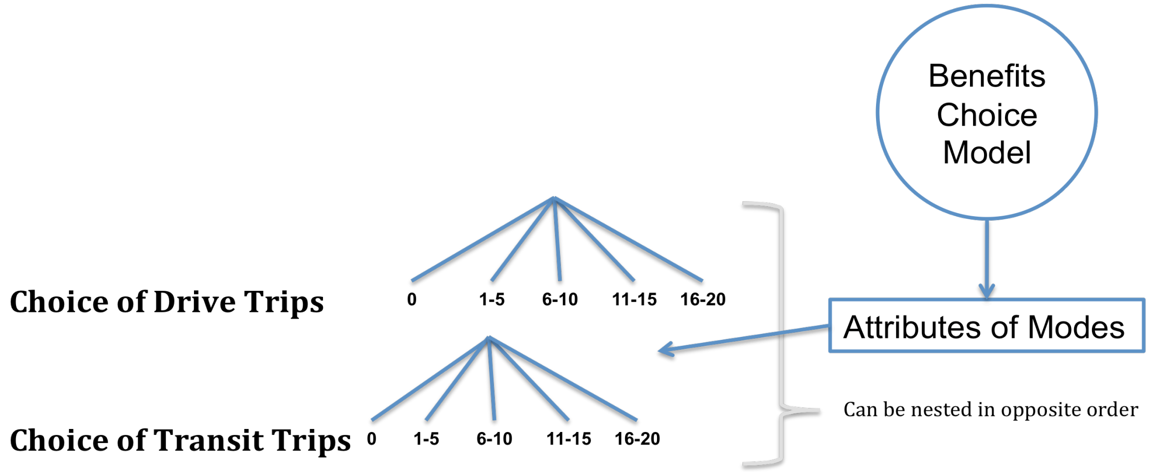
[15] Leaving aside for now the difference between actual and perceived costs.

Figure 7-1. "Ideal" Discrete-Continuous Model



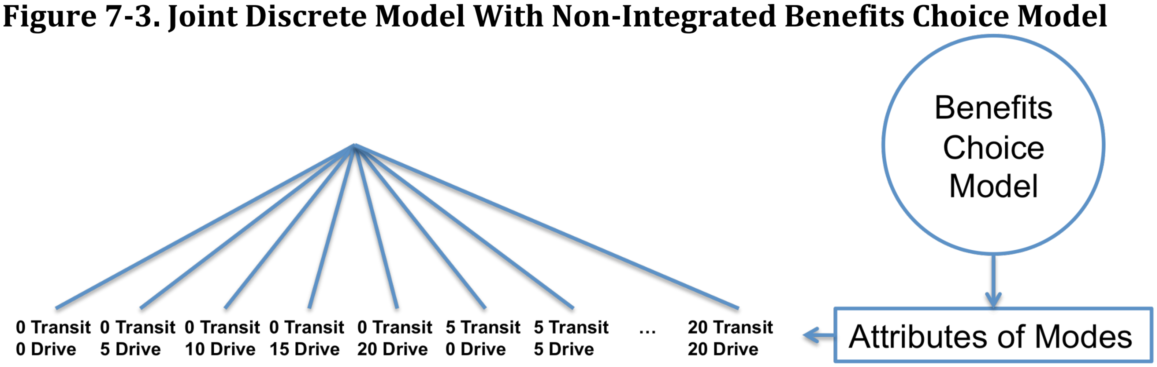
In this “ideal” model, the number of options to be considered is excessive, with no easy algorithm to reduce the size of the problem. In modeling just the number of transit and parking trips, there are approximately 400 combinations prior to grouping trips together (20 trips on each mode, and all the combinations thereof). Adding in the choice of benefits, even grouping them into the 5 main types (no benefit, monthly parking permit, occasional parking permit, occasional parking and transit pass, and transit pass), there are now 2000 combinations. The data set is not large enough to model this number of choices with any degree of accuracy. There are slightly fewer than 3,000 employees in the sample. In this “ideal” model, there are too many choices that will go un-chosen, and too many choices that will have very few observations in them. Even reducing the choice set by grouping the transit and drive trip combinations into just 25 choices, as shown in Figure 7-2, results in a model where just 24 employees will choose the average “category” of grouped transit and parking trips. Because each choice of the number trips is ordinal, rather than categorical, treating these choice as discrete and cateogorical is less than optimal. However, because of the decreased accuracy of these discrete choices initially, this thesis postulates that the precision of an ordinal choice model is misleading. Testing this assumption in more depth is necessary extension for further research.

Figure 7-2. Nested Discrete-Only Model With Non-Integrated Benefits Choice Model



Various nesting structures were tested to accommodate the expected correlation of error terms between alternatives with similar amount of trips by transit and/or auto, using the McFadden IIA test. The null hypothesis that IIA is valid between similar transit alternatives (that is, for all people who have 0 transit trips, 5 transit trips, etc.) cannot be rejected. However, neither can the hypothesis for any tested nesting structure that the scale parameter is different from 1 be rejected. That is, while there seems to be some correlation in error terms, a nested model is no more significant than a joint model. The results of the joint model, shown in Figure 7-3, are therefore presented throughout the rest of this Chapter.

Figure 7-3. Joint Discrete Model With Non-Integrated Benefits Choice Model



This thesis thus models the number of trips by transit (including non-commute trips) and by auto, but uses the attributes of the choice of benefits to define the costs of the independent variables. Note that the attributes of the passes and permits are being used, not the passes and permits themselves. These passes and permits modify the daily and monthly costs of travel to MIT. The model then has separate effects for the fixed and variable costs of travel by either mode. This means that alternatives can be added or modified without violating the Independence of Irrelevant Alternatives (IIA) assumptions of the logit model.

This model can be used to test the effects of policy options, but cannot predict the change in individual choice of benefits received. A separate model is needed to predict this choice. These choice predictions are used to change the attributes of the sample on which the choice of the number of trips by transit and auto to MIT is simulated. This is a system of models. The discrete choice model is dependent on the choice of benefits. In the model creation, those benefits are the actual elections by the individual. In the policy applications, those benefits are chosen under the assumption that a rational employee follows a policy of cost-minimization based on their desired activity patterns. Ideally, each model would feed into the other, so that they would be in equilibrium. But this would imply a false precision. Neither is the institutional constraint modeled. Parking supply must be constrained by eliminating leased parking in order to achieve savings to MIT necessary to fund new transit initiatives and move in the direction of equitable and sustainable policies. This means that model predictions are in a sense proxies, or shadow prices, that indicate the ease and depth of the choice to reduce parking supply. The full model of the choice of trips to MIT by mode is presented in Appendix 7.

7.2 Financial Model For Transit

The total cost of transit under the current subsidy regime at MIT requires attribution of the amount paid by employees and students and the amount subsidized by MIT. This is easily derived from MIT's records. A true accounting also requires examining the usage of the MBTA by those people who do not purchase an MBTA pass through MIT, whether because they are not allowed, or because they choose not to.

As can be seen in Table 7-1, employees are significantly more likely to purchase transit passes than students as whole, but graduate students who live off campus are more likely to purchase transit passes than all employees, most likely due to economic circumstances and their likely proximity to the campus. The only group with a significant number of people who commute to campus by car are employees. The graduate students with cars on campus are less likely to use them for commuting purposes, and more likely to use them for non-commute purposes. Lastly, the Commuter Rail subsidy is almost exclusively used by employees.

Table 7-1. Passes And Permits For On Campus, Benefits Eligible Students And Employees, November 2008

	On Campus, Eligible							
	All	Emp.s	Students	U.Grad On Campus	U.Grad Off Campus	Grad on Campus	Grad Off Campus	Ineligible or Off Campus
Non Passholders	45%	15%	68%	91%	78%	64%	50%	88%
Bus Pass Holders	1%	1%	1%	0%	6%	1%	1%	0%
Link Pass Holders	27%	32%	23%	7%	13%	19%	42%	3%
Commuter Rail Pass Holders	4%	8%	1%	0%	0%	1%	2%	0%
Pass Holders not through MIT	1%	2%	1%	0%	0%	0%	2%	?
Occasional Parkers (no pass)	3%	5%	0%	0%	0%	0%	1%	4%
Resident Permit Holder	3%	1%	4%	1%	1%	15%	1%	0%
Carpool Permit Holder	1%	2%	0%	0%	0%	0%	0%	0%
Commuter Permit Holder	15%	33%	1%	0%	1%	0%	1%	4%
Total	**18,191**	**7,979**	**10,212**	**3,026**	**974**	**2,485**	**3,727**	**5,747**

The distribution of transit passes affects cost attribution for the proposed changes to the current subsidy policies. If costs are spread across the population, groups with less usage of benefits will be donors to the program, while the groups with more usage will be the recipients of reductions in cost. If a Universal Access Pass is to include access to Commuter Rail, the implication is that students will be paying for employees' usage unless the employee and student pools are kept separate. Table 7-2 presents the total amounts spent by students and employees through MIT on transit passes, and the amount of those transit passes that are subsidized. The subsidy and payment amounts for Commuter Rail that are attributable to the LinkPass portion of the cost ($59, split evenly between MIT and students/employees) are attributed separately (Base and CR in the table below). This allows more exact attribution of costs within a Universal Access pass regime.

Table 7-2. Total Annual MIT Subsidy And Student / Employee Payments

			All	Emp.	Stud.	Ineligible or Off Campus
		Bus Pass Subsidy	$62,309	$29,876	$32,432	$2,343
+		Link Pass Subsidy	$1,572,446	$877,336	$695,110	$48,795
+	Base	Commuter Subsidy	$251,847	$227,031	$24,816	$5,760
+	CR	Commuter Subsidy	$567,780	$517,852	$49,928	$8,557
=		**Total MIT subsidy**	**$2,454,382**	**$1,652,095**	**$802,287**	$65,456
		Bus Pass Payments	$35,431	$16,989	$18,442	$1,332
+		Link Pass Payments	$1,572,446	$877,336	$695,110	$48,795
+	Base	Commuter Rail Payments	$251,847	$227,031	$24,816	$5,760
+	CR	Commuter Rail Payments	$567,694	$517,766	$49,928	$8,557
=		**Total Stud./Emp Payments**	**$2,427,418**	**$1,639,121**	**$788,296**	$64,445
=		**MBTA Revenue w/o CR**	**$3,746,326**	**$2,255,599**	**$1,490,727**	$112,786
=		**MBTA Revenue w/CR**	**$4,881,800**	**$3,291,217**	**$1,590,583**	$129,901

As can be seen in Table 7-3, the difference between the average annual Commuter Rail costs for employees is approximately $130, evenly split between MIT and the employee, whereas for students it is only $10. In these calculations, attribution for the portion of the Commuter Rail contributions and subsidy above the $59 cost of the LinkPass is differentiated. The "Base" portion of the employee / student contribution and MIT's subsidy is what the costs would be if the recipient only received a LinkPass. Without this modification, there would be an over-attribution of costs to Commuter Rail. For Universal Access programs, if Commuter Rail access is not included, assuming that the subsidy for these passes remains the same, than any decrease in the overall cost of passes decreases the base contribution of individual employees, but not the part attributed to Commuter Rail. In deriving these annual costs, the monthly costs have been scaled from November to a whole year. Passes sold decrease during the summer and during academic breaks. Therefore, rather than simply multiplying November's pass costs by 12, it is scaled by the ratio of total yearly passes sold between April 2008 and March 2009. For students this ratio is 10.0:1, and for employees it is 11.5:1.

Table 7-3. Average Annual MIT Subsidy And Student / Employee Payments

	All	Employees	Students	U.Grad On Campus	U.Grad Off Campus	Grad on Campus	Grad Off Campus
Total MIT subsidy	$135	$207	$79	$23	$57	$62	$141
Total Student/Emp Payments	$133	$205	$77	$22	$50	$61	$140
Current MBTA Rev. through MIT w/o CR	$206	$283	$146	$43	$103	$118	$260
Current MBTA Rev. through MIT w/ CR	$268	$412	$156	$45	$107	$123	$280

The average employee / student contribution can be read as the cost of a mandatory Universal Access Pass, if MIT does not change their total subsidy amount, and there is no usage of the MBTA by those students and employees who do not currently purchase a transit pass through MIT. This is essentially the calculation made by (Hester, 2004), although she did assume approximately $400,000 of irregular use by non-passholders, $200,000 for increased usage, and $100,000 in program costs. She calculated, based on 2003 data, that the total MIT payment to the MBTA absent this use was $3.4m, or approximately $1.4m less than the figures in this thesis. Including her estimate of program costs and increased usage, she found that a program without Commuter Rail would require a charge of $124 annually, with no additional subsidy increase from MIT. Without these costs her estimates come in at approximately $90 per person. Given the increase in subsidies in the subsequent years, it is therefore not surprising that a program with Commuter Rail, and without any estimated non-passholder use, or increase in usage would come in at $133 annually. If commuter rail contributions are removed, applying Hester's methodology to the updated costs in this thesis results in an annual per person cost of $102 annually. Baseline costs have grown 10% in the intervening years due to increases in the number of pass participants.

The findings in this thesis differ from Hester's because of more detailed data on how often those people who do not have a pass use the MBTA system. Hester's estimate was that the 15,000 people on campus who did not then purchase passes used $400,000 of fare value annually, or just over $26 per person. Hester's assumptions of $2-3 monthly usage of the MBTA system by non-passholders does not hold. Actually, in 2008, students who do not purchase a transit pass use $22-27 of value per month, rather than per year. Staff and Faculty without a transit pass or parking permit use $42 per month, as shown in Table 7-4. Even those employees who purchase a monthly parking permit average $8 per month of transit usage. If one moves to a Universal Access Pass regime, whether these costs are for commuting or non-commute usage is immaterial. The full cost derivations can be found in Appendix 8.

Table 7-4. Total Monthly Cost Of Individual Trips, By Staff And Faculty, By Type Of Pass / Permit*

Pass / Permit	Linked Trip Value	Bus Value	CR Value	Covered Usage	Uncovered Usage
None	$32	$2	$8	$0	$42
Bus Pass	$18	$26	$1	$39	$5
Link Pass	$86	$3	$3	$89	$3
CR	$15	$0	$190	$205	$0
Occasional + Bus Pass	$9	$30	$0	$36	$2
Occasional + Link Pass	$71	$2	$1	$73	$1
Occasional + CR	$9	$0	$165	$174	$0
Occasional Permit	$13	$0	$7	$0	$20
Carpool Permit	$9	$0	$2	$0	$12
Commuter Permit	$6	$0	$1	$0	$8

*Full results for students are presented in Appendix 8

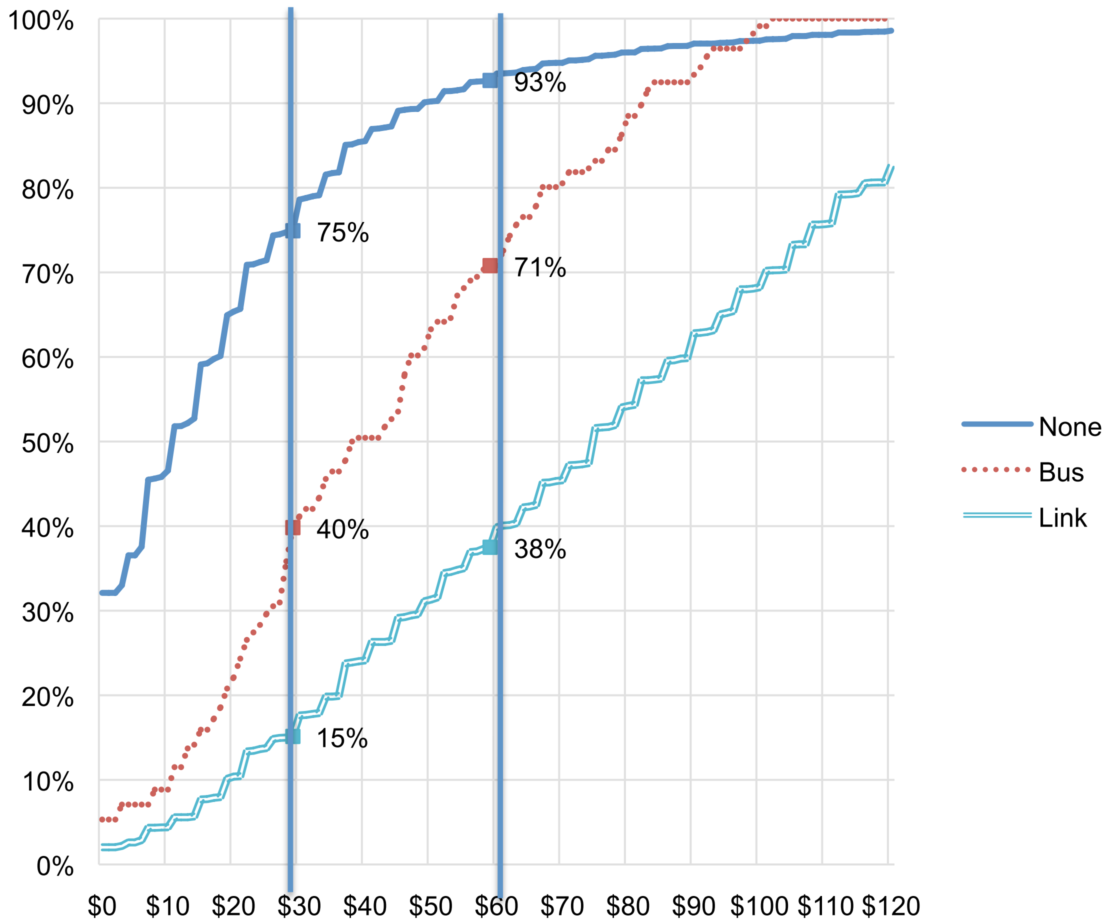
As shown in Table 7-5, there is an additional $800,000 of base transit costs for non-Commuter Rail usage by employees who do not have monthly passes through MIT or use service that are not covered by their passes. There is also $300,000 usage of Commuter Rail by these groups. For students, the usage is even larger. Students who do not purchase passes through MIT in aggregate use more non-Commuter Rail MBTA services, and more Commuter Rail, than those people who do purchase transit passes. Overall, for a program that includes Commuter Rail, rather than Hester's estimate of $400,000 additional usage, there is $3,000,000 of additional usage. None of this usage is subsidized by MIT. This means that the per-person increase in costs by including this usage is not $400,000/18,000 = $22 annually, but is instead approximately $3,000,000/18,000 = $162 annually. This amounts to doubling of the cost estimates of Hester for the program as a whole, without accounting for increased usage. The politics of a program that costs $10 per month, and one that costs $20 per month is quite different. Furthermore, most of this increase in costs comes not from people who park at MIT, but from people who do not participate in any of the benefits programs. A mandatory program requires participation from exactly this group. If MIT requires participation, but does not increase their total subsidy outlay, they are decreasing the costs for current transit pass holders at the expense of those people who have do not have passes and do not use transit. What the data shows is that many of the people who do not have transit passes do in fact use transit significantly, and would save money under a Universal Access Pass.

Table 7-5. Total Annual Cost Of MBTA Usage By Students / Employees, Including Non-Pass Usage

			All	Emp.	Stud.
		MBTA Revenue through MIT w/o CR	**$3,746,326**	**$2,255,599**	**$1,490,727**
		MBTA Revenue through MIT w/CR	**$4,881,800**	**$3,291,217**	**$1,590,583**
	Base	Non Passholder Revenue	$1,841,778	$377,028	$1,464,751
+	Base	Occasional Parker Revenue	$73,577	$65,011	$8,565
+	Base	Resident Permit Holder Revenue	$73,735	$5,560	$68,176
+	Base	Carpool Permit Holder Revenue	$21,668	$20,844	$824
+	Base	Commuter Permit Holder Revenue	$190,838	$185,121	$5,718
+	Base	Passholders not through MIT Revenue	$220,147	$137,804	$82,343
+	Base	Passholder non-covered usage	$13,334	$5,494	$7,840
=	**Base**	**Total Base MBTA Rev Not through MIT**	**$2,435,078**	**$796,861**	**$1,638,217**
	CR	Non Passholder Revenue	$270,492	$124,011	$146,480
+	CR	Occasional Parker Revenue	$40,253	$36,307	$3,946
+	CR	Resident Permit Holder Revenue	$5,844	$0	$5,844
+	CR	Carpool Permit Holder Revenue	$5,122	$5,122	$0
+	CR	Commuter Permit Holder Revenue	$42,411	$41,999	$412
+	CR	Passholders not through MIT Revenue	$26,508	$18,907	$7,601
+	CR	Passholder non-covered usage	$113,423	$77,924	$35,499
=	**CR**	**Total CR MBTA Rev Not through MIT**	**$504,053**	**$304,271**	**$199,782**
=		**Total MBTA revenue not through MIT**	**$2,939,131**	**$1,101,132**	**$1,837,999**
=		**Projected Payment to MBTA w/o CR**	**$6,181,404**	**$3,052,460**	**$3,128,943**
=		**Projected Payment to MBTA w/ CR**	**$7,820,930**	**$4,392,349**	**$3,428,582**

As seen in Figure 7-4, 35% of those people without a transit pass use more than $20 of bus and subway fare value on average per month, and only 25% use more than $29 of value. Equivalently, based on their usage patterns in November, 25% of people who did not purchase a LinkPass should have done so, if they were strictly cost-minimizing. That they did not could either be a result of lack of knowledge, or variable patterns. It requires 2 months to get on and off the program, and a trip to the parking office. If you only use transit a few months a year, because of other commute patterns, it may be perceived as an additional hurdle which offsets pure cost-minimization.

Figure 7-4. CDF Of Total Spend On MBTA Trips, By Passholding, November 2008, All Employees And Students



For those employees who have parking permits, but do not have transit passes, Figure 7-5 shows that fewer than 10% use more than $20 of value monthly, and approximately 5% use more than $30 of value. Little incentive exists for these employees to support a Universal Access Program based on cost, if they keep their current activity patterns. Removing those people from the non-transit pass holding population means that almost exactly 50% use more than $20 of value, and thus would benefit from a Universal Access program. Approximately 40% use more than $30 of value, and thus may not be making a strictly rational decision as to whether to purchase a pass currently. A Universal Access program automatically results in people making a decision that is cost-minimizing. This may or may not be met with objections, depending on how variable people's behavior is between months, and how much they value an automatically refilled card. The 10% of faculty and staff who do not have a pass, but use between $20 and $30 in value should perceive a required program as beneficial if it is priced at $20 monthly, as should those 10% of people employees who park and use transit more than $20 monthly, but are not currently allowed to purchase a subsidized transit pass through MIT.

Figure 7-5. Total Spend On MBTA On Per-Ride Basis, Staff And Faculty, By Type Of Pass/Permit; November 2008

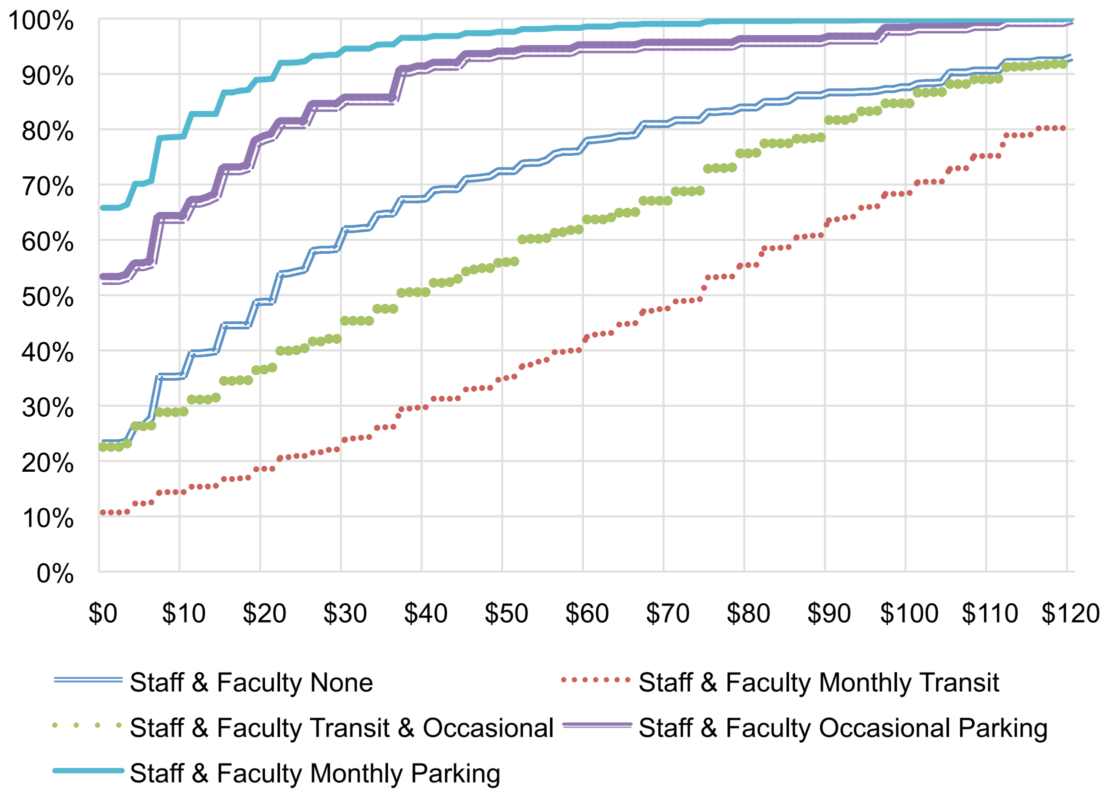


Table 7-6 shows that the monthly pass subsidy costs MIT less than a commensurate per-ride subsidy. Summing up the per-ride cost of employees transit results over an entire year results in costs $700,000 more than the annual pass cost. However, a per-ride program with an effective cap on the monthly price (either automatically, or via moving employees between per-use and monthly programs) is strictly cost saving. This is because it saves money for those employees who use less than the $59 that the pass costs MIT to provide, while keeping the $59 cap for those employees who use more. In other words, an individual cap is a "heads I win, tails I win" situation for MIT. If it results in more ridership, and thus more revenue for the MBTA, this also means that the MBTA will also gain, but if ridership increase is low, it could result in lower revenues. Thus, in evaluating these programs, the projected increased usage due to the program must be greater than the projected revenue loss due to capping in order for the MBTA to have an incentive to participate. These savings will appear as MIT converts employees to the pay-per-ride system.

Table 7-6. Comparison Of Per-Use And Monthly Pass For Current Passholders

	Base
Per Use Cost	$6,869,265
Monthly Pass Cost	$6,181,404
Savings from LinkPass Holders who use less than $59 of Value	$518,275

7.3 Financial Model For Parking

The parking side of the equation is somewhat simpler. The current operations and capital costs and number of people with permits determine the average subsidy per space. There are some complications, such as student spaces, leased spaces, and so-called space costs that make these attributions slightly less straightforward when attributing these costs to surface lots, structured aboveground garages, underground garages, and leased parking. The differences between these types of parking spaces are tied to the marginal costs of building parking to meet new demand, replacing existing parking due to construction, and removing existing parking because of changes in subsidy programs or other factors that reduce demand. This in turn feeds the costs and benefits of any change in the subsidy regime.

As is evident from Table 7-7, free spaces are distributed mostly in the West and Northwest area, both of which are more than 15-minute walk from the main part of campus. Thus, while they are "free," they are also low-demand areas. Attribution of free spaces by the Parking and Transportation Office (the "Assignment Ratio") is based on the following assumptions used by the parking office; people who have full time permits drive everyday and people with Occasional Permits drive 5 times per month. This is, of course, not exact, and, based on survey results, may overestimate the use of parking facilities on an average day. Thus, there are some areas that Table 7-7 suggests are over-allocated, even if there are very few days where a person with a permit cannot find a space in those areas. Based on the Parking Office assumptions, 96% of spaces are occupied on a daily basis. A more thorough count of daily usage under different conditions at each lot is required to validate or invalidate these assumptions.

Just over 40% of all spaces are in surface lots, 25% in aboveground garages, 15% in underground garages, and 20% in leased spaces. When the new Sloan Underground Garage opens in 2010, approximately 10% of the spaces on campus will change from leased to underground.

Table 7-7. Parking Spaces By Area, February 2009

		Total Spaces	Full Time Permits	Occasional Permits	Free Spaces
Owned	Westgate Area	385	416	128	-63
Owned	Northwest Area	340	214	10	124
Owned	West Zone	596	382	440	104
Owned	North Area	723	551	994	-77
Owned	Northeast Area	681	676	39	-5
Owned	Sloan and E51 Area	120	153	0	-33
Owned	Riverside Area	367	354	116	-16
Owned	Other Areas	517	412	253	42
Owned	Other Reserved	62	21	0	41
Leased	Tied to Leases	440	404	0	36
Leased	Tied to Construction	358	343	0	15
Leased	Tech Square	130	123	0	7
Owned	Surface Lots	1,991	1,759	557	93
Owned	Garages	1,119	744	1,384	29
Owned	Underground	681	676	39	-5
	Owned	**3,791**	**3,179**	**1,980**	117
	Leased	**928**	**870**	**0**	58
	Total	**4,719**	**4,049**	**1,980**	175
	Allocated Daily Occupancy	**96%**			
	Assignment Ratio		1	0.25	

If the goal is to change behavior, then it is important to focus on those spaces used for commuting, not for residential parking. As illustrated by Table 7-8, setting aside residential student parking spaces leaves 3,791 total spaces, of which 35% are surface, 25% are garages, and 15% are underground, and 25% are leased.

Table 7-8. Parking Spaces By Type

	Total Spaces	Student Spaces	Employee Spaces
Surface Lots	1,991	588	1,403
Garages	1,119	137	982
Underground	681		681
Total Owned	3,791	725	3,066
Total Leased	928		928

The costs associated with parking are allocated by space type based on MIT's Fiscal Year 2009 budget, operating through June 2009. This requires inference about the meanings of each of the budget line items, so while the numbers in Table 7-9 are presented as point estimates, they should actually be considered the middle of a range, which is plus or minus 10-15%. Operating expenses total just over $1.2m for all of the spaces owned by MIT. These costs are attributed equally by lot, since most of the costs of operation: enforcement, electricity and gating, etc. are invariant by type of space. These costs fall well within the range found in Chapter 2.

Table 7-9. Expenses By Type Of Space

	Operating Expenses	Interest, Depreciation, Space Charge	Total Cost	Operating / Space	Capital / Space	Total / Space
Surface Lots	$568,753	$2,118,787	$2,687,540	$405	$1,510	$1,916
Garages	$398,086	$1,934,920	$2,333,006	$405	$1,970	$2,376
Underground	$276,066	$2,976,400	$3,252,466	$405	$4,371	$4,776
Total Owned	$1,242,905	$7,030,107	$8,273,012	$405	$2,293	$2,698
Total Leased			$2,403,376			$2,590

Interest and depreciation total $4.8m annually. This has been attributed in Table 7-9, 80% to the underground spaces, and 20% to the garage spaces, based on the $100k per space estimate of the capital cost of the Stata Garage. The $2.6m in so-called "space charges" are attributed between garages and surface lots based on total lot size. These space charges are essentially the value to the Institute of the land if it were in its highest and best use. Therefore, attribution is based not on the total spaces, but on total land area used by the spaces in surface lots and garages. The result is that surface lots are more expensive than found in Chapter 2, mostly because land costs are higher for MIT than they are elsewhere. As previously noted, much of the land used by surface lots at MIT is in the only buildable space left on campus. The last two major building projects have been built on top of existing surface lots—the Cancer Research building and the new Sloan Building.

Removing non-employee parking revenue from total parking allows comparison of the costs of providing employee parking to the revenue from that parking. As shown in Table 7-10, total revenue is equal to $702 per space, as opposed to the $786 annual permit charge. This is likely due not only to unused spaces, but also to some permits that are less costly, such as those for retired (or semi-retired) Faculty and medical exemption permits.

Table 7-10. Revenue By Type Of Space

	Total Revenue	Revenue / Space	Imputed Free Space
Total Revenue	$3,313,467	$702	
Visitor and Other	$140,000		
Student	$336,487		
Parking Permits	$2,836,980	$710	9.63%

As seen in Table 7-11, underground spaces cost slightly more than 3 times the surface lots they replace. Leased parking and garaged parking cost the same amount, taking into account the value of the land and the capital costs. If the choice is between these two types of parking it is therefore not a cost decision, but an investment decision. Investing in parking is a commitment to continue those costs throughout their depreciation, whereas leasing spaces does not have the same commitment. Leased spaces tend to be on the periphery of the Institute, as opposed to existing garages. New aboveground garages are unlikely to be built in the center of campus, but underground garages may be. This then is the same cost tradeoff from Chapter 4. The differential in "profit" between leased and underground garages is a quantification of the value of proximity. If proximity is valued at more than $2,000 annually it is a strictly rational decision to build underground parking as compared to leasing. Additionally, while leasing spaces give MIT the option to terminate, the owner has similar options, so in the long run, if MIT wants the premium spaces it needs to pay the very high capital costs associated with underground parking.

Table 7-11. Profit / Loss By Type Of Space

	Cost / Space / Year	Revenue / Space / Year	Profit / Space / Year	Cost Recovery
Surface Lots	$1,916	$702	$(1,213)	37%
Garages	$2,376	$702	$(1,674)	30%
Underground	$4,776	$702	$(4,074)	15%
Total Owned	$2,698	$702	$(1,996)	26%
Total Leased	$2,590	$702	$(1,888)	27%

It is important to note the differential in cost between types of spaces. If MIT is replacing surface lot spaces with leased spaces, it costs $674 per space per year, without changing pricing at all. This takes into account the space being put to a higher and better use, and thus is the net cost of replacing surface parking. If MIT is replacing these spaces with underground spaces, it instead costs $2,860. If MIT chooses not to replace spaces lost by construction, it saves the cost of the surface lots, mostly in losing the space charges, which are a proxy for putting the land to its highest and best use. Reducing the amount of leased spaces results in immediate dollar savings to the Institute.

In the other direction, the total loss per marginal space is the amount that MIT could avoid if a parking space is eliminated without replacement. Assuming are 200 chargeable parking days in year, a transportation subsidy that increases costs $10 daily per parking space saved will be cost effective. This is based on MIT's ability to realize immediate cost savings from reducing leased parking. Over the long run the cost of the leased spaces will rise as demand increases and the inexpensive supply shrinks, with parking lots replaced with structured parking, and structured parking with underground.

7.4 BENEFITS ATTRIBUTION

These "models," in combination with the trip choice model developed in Appendix 7, permit evaluation of a hypothetical where neither parking nor transit are subsidized by MIT. This is the economist's "first best" world – where goods are priced at their value.[16] Comparing this hypothetical world to the real world allows assessment of effect of MIT's subsidy policies not only on employees, but to MIT's bottom line, the MBTA's revenue, and the cost of congestion to the City of Cambridge. This analysis assumes that absent subsidies employees choose between full priced monthly transit passes and parking at a market price of $250 per month.

[16] Of course, both auto usage and transit are already highly subsidized, so more accurately any reduction in subsidies by MIT takes us closer to a first-best world.

Transit and parking subsidies disincentivize travel by non-subsidized modes. Without these subsidies, Table 7-12 illustrates that the number of people who do not purchase benefits through MIT almost quadruples. Note that this has less effect on those people who travel mostly by transit, but never, or rarely drive. The increase in non-subsidized travel is not necessarily pedestrian behavior. It might also mean a significant increase in ridesharing, or being dropped off, since cost savings can still be achieved in that manner. In this non-subsidized world, employees may move closer to MIT, since they do not have the implicit $2,000 per year subsidy for their parking space. The $3,000 that a parking permit would cost them could be capitalized into $45,000 toward the purchase price of a house over 30 years at 5%. This might well affect location choices in the long run. It is important to note that the model is based on a single moment in time, and thus represents a long-run equilibrium. Changes based on policies also represent long-run equilibriums.

Table 7-12. Difference In Trip Distribution Between Current Subsidy Regime And "A World Without Subsidies"

	Transit CEQT*					
Parking CEQT*	**0**	**1 -5**	**6-10**	**11-15**	**16-20**	**Total**
0	388%	-26%	-20%	-15%	-8%	37%
1-5	-64%	-50%	-40%	-16%	-12%	-34%
6-10	-78%	-65%	-35%	-23%	-17%	-49%
11-15	-89%	-44%	-45%	-35%	-28%	-64%
16-20	-38%	-51%	-54%	-49%	-45%	-42%
Total	47%	-40%	-30%	-18%	-9%	

* See Appendix 7 for more detail on the ratio between CEQT and trips / parking events.

As can be seen by comparing the Table 7-13 and Table 7-14, this results in a significant drop in the total parking trips at MIT, so that MIT can save approximately 1,000 spaces on a daily basis. That is, not only does MIT charge, or allow others to charge more than 3 times the current rate, it saves the cost of building 1,000 spaces. MIT currently has almost 1,000 leased spaces, at a cost of $2,590 per year. MIT could save $2.5m from giving up leased spaces by removing its subsidy. In addition, each space that MIT owns currently costs just under $2,700 annually. At a monthly rate of $250, assuming that revenue is collected at approximately 90% of the total monthly rate, as it is now, MIT would then break even on its parking. In this situation any increase in parking that was an aboveground garage[17] would not be a decision to increase a subsidy, but instead a decision to meet increased demand. With market pricing, MIT's decision to build underground parking would likely not meet the cost recovery test.

[17] But the aboveground garage irretrievably eliminates the use of the land for buildings, and option which has been unacceptable to both MIT and the City of Cambridge.

Table 7-13. Summary Statistics For No Subsidy World

	Transit	Drive	Other
% Who Use Mode	55.0%	25.6%	50.9%
Total Monthly Trips	61,600	27,124	62,131
Mode Share	40.8%	18.0%	41.2%
Trips / Person / Month	7.32	3.22	7.38
Trips / User / Month	55.0%	25.6%	50.9%

Table 7-14. Comparative Statistics For Current Vs No Subsidy

	Transit	Drive	Other
% Who Use Mode	-14.4%	-19.9%	15.2%
Total Monthly Trips	-10,021	-22,075	32,623
Mode Share	-6.8%	-14.7%	21.6%
Trips / Person / Month	-1.19	-2.62	3.87
Trips / User / Month	1.04	-0.27	4.68
Days Parked		-20,671	
One Way Transit Trips	-27,571		

For employees, the difference between someone with and without a LinkPass is 32 trips per month. The decrease in transit trips is the equivalent of reducing the number of monthly LinkPasses sold by 862. Over a year, this results in decreased revenue to the MBTA of $610k. Attributing those costs to commuter rail as well results in an estimate 50% higher (the average monthly cost of a pass at MIT is $90 including commuter rail, rather than the $59 LinkPass). Chapter 6 used elasticity measures derived from those people with and without benefits to find an additional 700 passholders resulting from MIT's 50% transit subsidy. These two measures agree – MIT's subsidy increases the number of MBTA passes which employees purchase by 25-35%.

The coalition in support of subsidies is self-sustaining. The subsidies exist, which causes people to use those subsidies, and in turn makes it a difficult decision to remove them. The lack of those subsidies could also feed its own positive feedback loop. An additional 1,000 people walking, biking, getting dropped off or ridesharing would change the constituencies at MIT significantly. If they all walked, the sidewalks of Massachusetts Avenue and Main Street would be more active. If they biked, the bike lanes would be full. If they were dropped off, the curbs would be packed.

The reduction of 20,000 trips per month by auto to MIT means fewer people driving in Cambridge (inasmuch as they are not all dropped off by a different car that would otherwise not have made the trip). As of 2006, there were approximately 11,000 daily vehicles on each of Massachusetts Avenue and Main Street nearby MIT. (Executive Office of Transportation, 2007). Splitting the difference would mean a reduction of 10% in traffic on those corridors each day (assuming each parking event would result in 2 drive trips, at 20 trips per month). If it was leased spaces only that were eliminated, most of those are entered in the vicinity of Main Street.

Because a small reduction in traffic can significantly improve congested conditions, these reductions may make a difference in traffic flow.

Recall from Chapter 4 that one of the reasons MIT has subsidized transit is to avoid additional congestion mitigation measures imposed by the City of Cambridge. While these transit subsidies seem to have increased usage by 600-800 people, they have not completely offset the 1,000 additional people that drive every day due to MIT's parking subsidies. This would seem to indicate that traditional TDM measures that are "all carrot" are not necessarily the most effective means by which the City can meet its goals. Even a full 50% transit subsidy ($29.50 to $125 monthly depending on the pass) is not enough to offset the effect of a 70% parking subsidy ($150 per month).

7.5 Business As Usual Projections

The high cost of providing parking is a comparatively new development. The first underground lot at MIT was built less than 10 years ago. Even though the current growth path for the University is on hold, in the next 10 years MIT is likely to return to the growth it exhibited in the previous 10 years. At the very least, facilities will continue to depreciate. Buildings will need to be replaced. This usually means rebuilding them in different locations. Structured parking lots too have a useful lifespan. In the next ten years the West Garage will likely be fully depreciated, and even closer to the end of its useful life.

7.5.1 Employee Growth

To project increases in the cost of parking and transit due to growth in the number of employees requires a series of assumptions about that growth. This section begins with the assumption that mode shares remain stable for current faculty and staff. This assumption is then extended to include the effects of age cohorts. Recall that the cohort effect is the inference that mode choice is not determined by lifecycle, but instead carries with people as they age. By this assumption the explanation for why younger people are more likely to take transit than older people is not because they live closer, do not have children, etc., but because they are forming activity patterns based on different environmental concerns, mode costs, etc. If this is true the expected effect is a naturally occurring decrease in SOV commutes.

MIT has seen approximately a 1% annual increase in the total number of employees over the last decade. (Boes, 2008) MIT adds approximately 80 employees per year. Recall from Chapter 6 that the average drive mode share is 28.2% across all employees; an additional 8.2% rideshare. Just over 90% of the SOV travel and just under 50% of the rideshare trips result in a parking event on campus. By extension, 29.5% of all new employees' daily commutes result in a parking trip. Both those people who have left MIT recently and those who have joined are younger on average than those who stay. If the cohort theory is valid, then by Table 7-15 only 15% of new employees require a parking space. Alternatively, if new employees are joining, but changing their mode share as they age, then expected mode shares need to be adjusted between years for those people who "graduate" into parking as they age. In this case, a good approximation of these dynamics is to subtract the difference between those people who start and those people who leave from the average mode share for the entire population. In this case, 25.9% of all new employee trips result in a parking event at MIT.

Table 7-15. Age & Mode Share Differential For Existing, Leaving, And New Employees

	Age as of Survey	Drive Mode Share (weekly)
Remained at MIT	49.1	33.9%
Started in 2008	33.6	15.1%
Left after 2006	35.5	18.6%

Assuming the same growth patterns of the last decade, as shown in Table 7-16, MIT will require an additional 38 to 75 parking spaces over the next 3 years, 65-127 over the next 5, and 133-260 over the next 10. Without data to verify the correct case, this thesis assumes that while aggregate patterns reduce drive trips, people will continue to drive more as they age and their activity patterns change. The middle estimate of parking growth is therefore used throughout the remainder of this thesis. Costs from this parking growth are heavily reliant on whether new spaces need to be constructed or leased in order to meet it. Furthermore, over 20 years, the growth cannot be accommodated under MIT's de facto parking cap, so it would subject MIT to mandatory mitigation measures from the City of Cambridge. Under the assumption that the new parking demand is filled with new leased parking, in 2019 these spaces would cost MIT $592,000 annually, only 27% of which would be recovered at current parking rates. If increased demand requires building new underground spaces, the cost to MIT is $1.1m annually, only 15% of which would be recovered from current parking rates.

Table 7-16. Projected Parking Demand For MIT Growth Vs. Business As Usual

		Total New Daily Parking Trips		
Year	Employees	Max	Middle	Low
FY09	8,426			
FY10	8,510	25	22	13
FY11	8,595	50	44	25
FY12	8,681	75	66	38
FY13	8,768	101	89	52
FY14	8,856	127	111	65
FY15	8,944	153	134	78
FY16	9,034	179	158	92
FY17	9,124	206	181	105
FY18	9,215	233	205	119
FY19	9,308	260	229	133
,,,				
FY29	10,281	547	481	279

Employee growth also results in commensurate increases in trips by transit. There are two measurements that are important here – both the number of passes sold, and the number of trips taken. The methodology used in the following section to derive estimates for these increases is similar to that described above. As shown in Table 7-17 overall transit mode share is 35.7%. The average monthly value of the trips taken is $49, based on the distribution of trips on subway, bus and commuter rail. The average monthly subsidy across all employees (including people who do not purchase a transit pass through MIT) is $17.51. Those people who started in 2008 use transit more regularly and purchase more passes than both those people who left after 2006, and those people who remained employed by MIT.

Table 7-17. Comparison Of Public Transit Fare And Pass Usage For Existing, Leaving, And New Employees

	Public Transit			Pass Types			
	Mode Share	Monthly Trips	Value	Bus	Link	CR	Pass Subsidy
All Employees	35.7%	23.9	$49.26	1.3%	30.8%	8.4%	$17.51
Remained at MIT	28.0%	19.1	$41.98	1.7%	25.5%	10.0%	$17.67
Started in 2008	49.3%	33.7	$65.56	0.7%	39.6%	6.6%	$18.27
Left after 2006	44.6%	29.3	$56.95	3.1%	36.1%	6.9%	$18.14

The maximum estimates shown in Table 7-18 are based on trips and pass purchases by those people who began employment in 2008; low estimates are based on all employees; medium estimates are all employees, plus the difference between those who left after 2006, and those who started in 2008. Similar to above, this thesis assumes that the middle estimates are likely to be closest to actual behavior, taking into account changing behavior over time. Over the next 3 years, due to natural growth, this results in an increase of almost $55,000 in subsidy costs and $155,000 in actual usage, rising to $188,000 and $535,000 over the next 10 years. This is a growth rate in the usage of transit of approximately 12.2%, and in subsidy of 11.4% over 10 years, given a 1% annual increase in the number of employees.

Table 7-18. Growth Estimates For Total MBTA Usage And MIT Subsidy

		Fare Value			Subsidy Value		
	Emp.s	Max	Middle	Low	Max	Middle	Low
FY09	8,426						
FY10	8,510	$66,288	$51,151	$49,806	$18,473	$17,993	$17,703
FY11	8,595	$133,240	$102,813	$100,110	$37,131	$36,167	$35,584
FY12	8,681	$200,861	$154,991	$150,917	$55,976	$54,522	$53,643
FY13	8,768	$269,158	$207,692	$202,232	$75,009	$73,060	$71,883
FY14	8,856	$338,138	$260,919	$254,060	$94,232	$91,784	$90,305
FY15	8,944	$407,808	$314,679	$306,406	$113,648	$110,696	$108,911
FY16	9,034	$478,174	$368,976	$359,276	$133,257	$129,796	$127,704
FY17	9,124	$549,245	$423,817	$412,675	$153,063	$149,087	$146,684
FY18	9,215	$621,025	$479,206	$466,608	$173,067	$168,571	$165,854
FY19	9,308	$693,524	$535,148	$521,079	$193,271	$188,251	$185,216
…							
FY29	10,281	$1,459,606	$1,126,285	$1,096,675	$406,762	$396,196	$389,810

7.5.2 Institutional Growth

The preceding sections of this Chapter and Chapter 4 established that the remaining buildable locations on campus are primarily existing surface lots. This thesis assumes that the decrease in available spaces, and thus the demand for an increase in leased or newly built spaces, is relatively independent of any growth in the number of employees. Buildings deteriorate; facilities no longer meet the technology needs of new types of research. New buildings need to be built, even if the overall population of MIT does not grow. If the old buildings are converted to classroom space, or otherwise re-used, there is no new open space on which to park cars. Even if they are torn down, demand for open space on campus is such that it is unlikely that the new open space is used for parking.

Removing the surface spaces on the outskirts of campus, and the minor lots that are unlikely to be able to accommodate new construction, there are 966 surface spaces on campus in use by employees on buildable areas. Absent any actual plans to redevelop those areas, an estimate of the number of spaces that would be lost over the next 10 years is based on the number of spaces per employee lost over the last 10 years. This is not an exact estimate – land is not fungible, and growth is not constant. Based on the loss rate over the last 10 years, between 150 and 350 spaces will be lost over the next 10 years. If there is employee growth, spaces lost are likely to be at the high end of the range, as more space is needed to accommodate growth.

7.5.3 Growth Scenarios

There are two edge scenarios for MIT over the next 10 years: no growth, and growth at the same rate as the last 10 years; 1%. To calculate the costs of parking over those years under the business as usual subsidy regime requires an estimate of empty spaces in the system. This in turn requires judgment of the political will to reduce that slack, and thus increase the probability that someone with a permit will come to campus and not be able to find a spot easily, or at all. Previous calculations show that there are about 175 spaces that are not currently allocated (5% slack in the system), and anecdotally more that are not used on a daily basis. At 95% allocation, on high demand days a permitted parker should be able to find space on campus to park, even if it requires time and/or effort. At 100% allocation, on high demand days the difficulty of parking on campus is likely to be tight. This thesis uses the assumption that half of the current slack in the system could be eliminated without undue difficulties placed on permit holders. There are therefore 88 spaces of slack. The first 88 spaces due to increased demand need not result in any increase in costs.

Even under the no growth scenario, which seems unlikely, Table 7-19 illustrates that over the next 10 years MIT will need to build an additional 62 spaces to meet increased demand. Under the growth scenario, MIT will need to build almost 500 spaces, at a cost of between \$1.3m and \$2.3m annually. They will also need to spend between \$188k and \$535k on increased transit subsidies (or usage, under a Universal Access pass program) due to growth. Neither of these scenarios is likely to be borne out exactly – the truth is somewhere in the middle. If MIT hews closer to the growth scenario, not only are there pressures against the parking cap, there is demand equivalent to a new underground garage almost the size of the soon to be completed Sloan Garage. At $100,000+ in capital costs per space for the Sloan Garage, this would mean an investment of close to $50m in 2009 dollars to meet increased parking demand on campus. The likelihood of any demand being met by leased spaces is small. As explored in Chapter 4, leased spaces require cash outlays. They do not come from donations, or other funding source. On the other hand, the capital costs of constructing underground garages may be partially offset by MIT's generous alumni, but these are potential donations competing with core MIT facilities that directly impact the mission of the Institution, such as laboratory and library modernization.

Table 7-19. Projected Savings And Costs From Growth And No Growth Scenarios Vs. Business As Usual

		FY12	FY14	FY19
No Growth	Spaces	0	0	62
	Replace w Leased	$0	$0	$160,570
	Replace with Owned	$0	$0	$296,113
Growth	Spaces	66	198	491
	Replace w Leased	$170,203	$514,023	$1,270,679
	Replace with Owned	$313,876	$947,926	$2,343,300
	Transit Trips	$154,991	$260,919	$535,148
	Transit Subsidy	$54,522	$91,784	$188,251

Therefore somewhere between 60 and 500 surface spaces are likely to be replaced by underground garages over the next 10 years under a business as usual scenario.[18] Assuming that some growth will occur, MIT will see an increase in the annual costs of parking facilities of at least 1.5% annually over this period, absent any inflation. If the 11% annual increase in parking costs (assumed to be 7% above the long-term rate of inflation) manages to continue over this period, the $1,890 annual subsidy per space will decrease to $1,625. MIT's subsidy for parking, even assuming that an 11% annual increase is sustainable for employee morale over the next 10 years, will only decrease by $265 per year. If the sustainable parking price increase is less than 9%, than MIT's subsidy for parking will grow in real terms. If parking costs continue to grow greater than the rate of inflation, or if there is more growth in employees or replacement of surface spaces, than MIT's costs for parking will only increase over the next 10 years.

7.6 UNIVERSAL ACCESS PASS PROGRAMS

Given that MIT's costs for parking are stable or increasing even in an optimistic business as usual scenario, the operative question is whether the proposed Mobility Pass will effect behavior, and thus reduce those costs? At MIT's current aggregate level of subsidy for transit passes, the calculation of the price for a Universal Access

[18] Business as usual is a somewhat misleading term given MIT's leadership position with 50% transit subsidies for employees and students.

Pass is relatively straightforward. Universal Access Passes distribute the cost of travel by transit across the entire population of an affinity group. Thus, per person costs are the aggregate value of transit usage by students and employees at MIT divided by the total population. This calculation assumes that there is an effective cap on usage for each employee at the cost of the transit pass. This cap need not be implemented through an automatic mechanism. As discussed in Chapter 4, one proposal on the table is to allow MIT to move people between the existing Corporate Pass sales program run by the MBTA and a Pay-per-ride pass program where MIT is responsible for the individual fares. MIT would monitor the total fare value usage of each individual's cards in the pay-per-ride program and move employees who use more than the fare value of a monthly pass to the monthly pass program. MIT would have no information on individual's transit behavior besides their total usage. This would avoid any negative privacy implications. To the employee the transition between programs would be seamless. To MIT, it would provide an effective cap on the cost of an individual's pass at the level of a monthly pass.

The reduction of costs for MIT is an important, but not and exclusive metric of success. As established in Chapter 5, it must also meet MIT's goals of employee recruitment and retention, decrease Institute emissions and carbon dioxide, provide a more dependable and higher revenue stream to the MBTA, and decrease congestion in the City of Cambridge. The following section evaluates the policy options proposed in Chapter 5 against these requirements. It begins with the simplest program, which requires participation of all employees and spreads the cost equally. It proceeds to explore variants of this program that distribute the costs in other formulations, and are not mandatory. Finally, it evaluates a separate program that is a stepping stone to a full Universal Access Pass; the so-called Half Pass, where the costs are half what they are for a full pass, but the allowed trips are no longer unlimited.

7.6.1 Mandatory Pay-per-ride Universal Access Pass

Given the total usage of the MBTA system by MIT employees and students of $7.8m, under a mandatory Universal Access Pass, each of the 18,191 on-campus, eligible members of the MIT community would need to pay $430 per year for a pass that includes unlimited access to all MBTA services, including commuter rail. However, if MIT's current $2.4m transit subsidy is distributed across the student and employee population, the cost is reduced to $295 per person. If instead MIT decided to keep the commuter rail price at the current 50% subsidy level on an individual level, rather than distributing those costs across the population, the total cost would be $340 per person, of which $104 is subsidized. In other words, the pass would cost each person $236 per year (just under $20/month), and would apply to all service currently covered by the LinkPass.

The first alternative is not viable because the MBTA has yet to implement payments via the CharlieCard for commuter rail, and thus there is no way to account for non-passholder usage. Thus, only the LinkPass equivalent option is evaluated throughout the remainder of this thesis. To convert these programs to one that includes Commuter Rail add $60 per year to the cost of the programs that cover both employees and students. Because students and employees have different usage patterns, add $100 annually to the cost of an employee-only program, but only $24 to the cost of a student-only program. In other words, one could give full access to the Commuter Rail system to students for an additional 10%, still almost $8 per month lower than the current cost of subsidized LinkPass ($29.50). It would increase the cost of a Universal Access pass by more than 40% for employees, but will still cost $2 per month less for employees than the current LinkPass, which does not provide access to the Commuter Rail system.

None of the estimates thus far include increased usage due to the pass. Universal Access Passes eliminates the marginal cost for all employees, and reduce their total cost. Application of the model from Appendix 7 allows quantification of the increased usage of transit, as well as a decrease in the number of people parking.

Applying this model, the results of which are presented in
Table 7-20 and Table 7-21, there are significantly fewer people who never take transit. This makes intuitive sense; there is no cost for them when they do. People move from parking every day to parking less often, but very few cease parking. That is, it gives people the flexibility to change their commute choices, but does not stop people from optimizing their commute choices for their activity patterns. Most of the increase in transit usage comes from those people who do not currently receive a transportation benefit, nor are they recorded parking at MIT or report using transit. These are the people who currently walk or bike or are dropped off exclusively. However, under this program they are "required" to get a transit benefit.

Table 7-20. Distribution Of Changed Behavior By Employees, Mandatory $20 Universal Access Program

	Transit CEQT*					
Parking CEQT*	**0**	**1 -5**	**6-10**	**11-15**	**16-20**	**Total**
0	-519	-295	-61	159	769	52
1-5	-160	-32	53	130	406	397
6-10	-113	-9	57	98	177	211
11-15	-175	-15	25	75	88	-2
16-20	-974	-19	167	116	54	-657
Total	-1,942	-370	240	578	1,494	

* See Appendix 7 for more detail on the ratio between CEQT and trips / parking events.

Table 7-21. Summary Statistics, Employees, Mandatory $20 Universal Access Pass

	Transit	Drive	Other
% Who Use Mode	92.4%	44.9%	22.0%
Total Monthly Trips	106,829	40,215	12,681
Mode Share	66.9%	25.2%	7.9%
Trips / Person / Month	12.69	4.78	1.51
Trips / User / Month	13.73	10.63	6.86

The percent of people who drive to work, as shown in Table 7-22, decreases very slightly, even while drive mode share as measured by total trips to MIT decreases by 7.6%. The increase in transit trips is also drawn from those people who formerly walked, biked, were dropped off, etc. People who use transit use it more often on average, and people who drive, drive less often. The total cost to MIT of a transit pass, and the average annual fare value of a recorded monthly trip (just over $16) allows derivation of the cost of transit.

Table 7-22. Change From Current Behavior, Employees, Mandatory $20 Universal Access Pass

	Transit	Drive	Other
% Who Use Mode	23.1%	-0.6%	-13.7%
Mode Share	19.2%	-7.6%	-11.7%
Trips / Person / Month	4.18	-1.07	-2.00
Trips / User / Month	1.46	-2.20	-2.97

Attribution of the increase in usage for students is slightly more difficult, and requires a series of assumptions. (1) All students on campus and undergraduates who live off campus will continue to predominantly walk or take the campus shuttle system. Their activity patterns are unlikely to undergo a wholesale change as a result of this policy, but they are likely to take more transit. Based on the University Pass case studies in other areas, a high estimate of a 15% increase in usage for these students is assumed. (2) Graduate students who live off campus, and have transit passes are unlikely to change their activity patterns because of a decrease in cost. (3) Graduate students who do not have transit passes are similar in behavioral change to employees and faculty who neither drive nor take transit to MIT.

Most of the employee cost comes from those employees who formerly did not receive benefits, and only took transit occasionally. With the mandatory Universal Access Pass, the model predicts that over 60% of these employees begin using transit regularly. It also predicts that approximately 25% of the people who have a monthly parking permit begin using transit regularly, but only park somewhat less—most of their increase in usage is non-commute. These numbers are high estimates for the increase in transit use due to Universal Access Pass program. They may be accurate in the long-run, but in the short-run activity patterns are more ingrained, even if they are not mediated by habit. Nevertheless, the implication is that, even with the savings from leased parking put back into the program, without increasing current subsidy levels MIT would have to charge $284 annually for the program, rather than $236.

With the increase in expected usage, at the current subsidy levels, this program would result in a $74 savings off the annual cost of a subsidized LinkPass for each person, as seen in Table 7-23. Of course, this is not a fair comparison. Under a Universal Access Pass MIT subsidizes not 30%, but 100% of the population. Under the current regime this would increase MIT's subsidy by $3.9m annually. Without increased subsidy levels, MIT receives the benefits people having zero marginal cost access to transit without the cost of actually increasing their subsidy. If MIT were to allocate the $40 annual subsidy required to reduce program costs to $20/month, it would cost them only 1/5th of this amount; $730k.

Table 7-23. Revenue And Cost Effects Of Mandatory $240 Annual Universal Access Pass

Spaces Reduced	336
Lease Savings	$871,459
Transit Cost: Employees	$1,436,916
Transit Cost: Students	$758,646
Savings from moving LinkPass holders to pay-per-ride	$518,275
Total Increase in MBTA Revenue	**$1,677,287**
Total implied cost of Mobility Pass (annual)	$284

Under this pass, the MBTA increases their revenue by $1.6m annually, or more than 20%. They no longer are collecting cash fares from individuals, but instead are receiving a lump sum payment from a large institution. The money is more consistent and the transaction costs are decreased.

From an environmental perspective, the effects are unclear. Many of the new employee transit trips come from trips that were formerly biking, walking, being dropped off, or parking off campus. The number of trips attributed to each of these modes is therefore key. Inasmuch as no service increases are required, there is no increase in emissions from increased public transit usage. The 336 average daily driving trips to MIT from people who park at MIT are a 10% reduction in direct VMT and congestion emissions from commutes to campus on a daily basis. The increase in non-commute trips via transit by drivers implies that there is a decrease in total emissions from non-commute trips as well, but it is not likely to be for all of the non-commute trips. Including the long term reductions in vehicle ownership, total emissions decrease from a mandatory Universal Access Pass is greater than the implied 10% direct transportation related emissions.

The 600+ fewer daily one-way trips by auto to MIT reduce congestion somewhat in Cambridge. However, it does set MIT up for better positioning in the long run, based on business-as-usual growth projections. A reduction in drive alone mode share of 7.6% means slowing annual growth in parking spaces required by 6 per year in the growth scenario. The 336 spaces are an immediate savings in either scenario. In the long run they result in avoided construction costs. The $2,500 annual savings per space from leased parking in the short-term turns into $4,750 annual savings from avoiding construction in the long run. Over 10 years this means that only 93 new spaces need be constructed rather than 491 in the growth scenario, or that 336 spaces are foregone, rather than 62 needing to be constructed in the no-growth scenario. Spaces foregone are valued at the cost of leasing, whereas spaces that do not need to be constructed are valued at the cost of constructing those spaces. This results in an annual savings of $1.2m in the no-growth scenario, and $1.9m in the growth scenario. This analysis assumes that the short run savings of $900k annually are being used to fund the Universal Access program. MIT sees a net gain of $300k-$1.1m annually by the 10th year because of this program, for a total of $2m-$6m over 10 years.

Overall, by Table 7-24, approximately 59% of employees stand to save money in the program without changing their commute patterns. This is 5% higher than it would otherwise be, without the pre-tax advantages of employee contributions. If the model is correct that a majority of the non-passholders and a large fraction of the monthly parkers change their patterns because of this change in cost, than the mandatory Universal Access Pass is economically beneficial to 80%+ of employees. However, the level of support is unlikely to be above the 59% who benefit without changing their patterns. One tends not to win support by requiring participation in a program, even if it is beneficial to constituents.

Table 7-24. Expected Employee Support Of $20 Mandatory Universal Access Pass

	Employees	Program Cost (after tax)	Expected Support	Reason
Non-Passholders	1,330	Cost additional $13/month	60%	use $13+ of value currently
Monthly Parkers	3,288	Cost additional $213/month	17%	use $13+ of value currently
Bus Passholders	102	Cost additional $4/month	75%	use $4+ of additional value
Link Passholders	2,589	Save $6 per month	100%	Savings
CRI Pass holders	670	Save $6 per month	100%	Savings
Total Support			**59%**	

7.6.2 UNIVERSAL ACCESS PROGRAM OPTIONS

There are other options for Universal Access Pass programs beyond simple equalization of costs. For example, costs can be allocated to equalize the after-tax cost to employees and students. Students do not qualify for pre-tax payment of transportation benefits. Under the assumption that the average combined Federal and FICA taxes for employees are 33%, the post-tax pass cost for employees is 67% of the student cost. Equalizing after-tax payments results in a charged pass cost of $194 annually for students, and $290 for employees, before the additional usage calculated in the prior section. This does not affect MIT's monthly costs, nor does it affect the MBTA's revenues

Rather than allocating post-tax costs, allocating costs based on the actual usage by these groups results in little change to total costs: students would pay $233 annually, while employees would pay $240. In large part this is because, while a higher percentage of employees currently participate in the subsidized transit pass program, very few students have cars available to them. Thus even those non-participants use more transit on an average basis.

Rather than a Universal Access Pass, MIT could follow part of the University of Washington model, and either offer a free Universal Access Pass to people who currently have monthly parking permits, or require them to purchase a Universal Access Pass at an additional cost above their current parking permit. This would remove all of the costs from the non-participant groups, while still retaining the savings in reduced parking from those people who currently park. On average, employees with a monthly parking permit use $74 of fare value on non-commuter rail MBTA services annually. Thus, a $74 annual charge for an Unlimited Access Pass for these employees would result in a net cost to MIT of $0, since the entire current usage would be paid for by those employees who park. Including the tax benefits, a pass of $111 per year would result in an average $0 net cost increase to employees.

Per Table 7-25, at a per pass cost of $8 per month, the increase in transit usage and decrease in parking are similar to the mandatory Universal Access Pass, but without the same costs for students and non-parkers. Under the assumption that MIT moves all LinkPass holders who use less than $59 of value to pay-per-use programs, they are able to capture the excess payments for those people. Without the savings from leased parking, this program costs MIT an additional $80 per person per year above their current program costs. However, with the savings from leased parking—one of the goals of the program—MIT saves $203 per employee with a monthly permit. Employees are paying $96 of this savings. The implication is that MIT could give an Unlimited Access pass to parkers, and still see cost savings of over $100 per current parker per year. With approximately 3,000 employees with a monthly permit on campus, this policy would save MIT approximately 300k annually, while increasing the MBTA's revenues by almost the same amount. On average, no employees would be harmed. Those people who changed behavior would do so voluntarily. Those parkers who did not change behavior would have their existing transit usage paid for. It would decrease emissions from journey to work transportation by at least 8%, and slightly reduce local congestion.

Table 7-25. Annual Revenue And Cost Effects Of $96 Annual Mandatory Pass Program For Monthly Permit Parkers

Spaces Reduced	312
Lease Savings	$808,283
Transit Cost: Employees	$810,187
Savings from moving LinkPass holders to pay-per-ride	$518,275
Savings from increased employee deductions	$18,144
Total Increase in MBTA Revenue	**$291,912**
Mobility Pass per person cost increase, with leased savings put into program	-$91

The perceived risk in giving away the pass is if people do not change their behavior; they use it for non-commute use, but do not reduce the number of days they drive to MIT and park. This would amount to a total of $205k in usage by these employees. The counter this, MIT could offer the Unlimited Access Pass as an optional add-on for people who park at the estimated total value, $74 annually. In this scenario people would be less likely to participate based on cost minimization for their existing travel patterns than they would if they were given the pass or were required to pay a surcharge for the pass. Rather than needing to make use of something that they had paid for, the rational model used in this thesis predicts that only the 30% of people with a monthly parking permit whose current activity patterns have them spending at least $4 of fare value per month (taking into account the benefit of purchasing the pass on a pre-tax basis) would opt in to the program.

Based on rational expectations, pass behavior was simulated in the model. By opting in these committed parkers have given themselves an incentive to act more flexibly – to take more transit and therefore to park at MIT less often. Thus under a strict assumption of rationality to meet existing mode choice patterns, there is an increase in transit usage and decrease in parking at MIT. As shown in Table 7-26, this increase in transit usage much smaller than that found in the prior "free" pass example. The savings from foregoing leased parking almost exactly offsets the increase in usage. It improves employee's lives, without costing MIT anything to provide. Inasmuch as it serves as a recruitment and retention measure, it is net positive for the Institute. Moreover, it meets the same principles outlined in Chapter 5; it is voluntary, and can be purchased by any employee at MIT, so long as they have a parking permit. While the leased parking savings offset the increased usage in the short term, over the long run greater savings materialize. Based on the model, total parking at MIT decreases by 3%. Applying this reduction to new employees, by FY19 the savings to MIT increases by $200k annually for the no growth scenario and $375k annually in the growth scenario, taking into account increased transit usage vs. the business as usual scenario. This is a program that is revenue neutral in the short-term for MIT, and cost savings in the long run.

Table 7-26. Annual Revenue And Cost Effects Of $74 Annual Opt-In Program For Monthly Permit Parkers

Spaces Reduced	117
Lease Savings	$303,405
Transit Cost	$307,929
Total Increase in MBTA Revenue	**$307,929**

The $74 annual opt-in program increases MBTA revenues by 7% over MIT's current payment. However, because it does not significantly increase the number of people who receive transit passes, it is unlikely that MIT can combine this program with moving LinkPass holders to the MIT Pays-per-use program. Doing so would result in a net decrease in payments to the MBTA. By restricting the program in this way, MIT gives up $500k in annual savings. It also significantly reduces the emissions reductions and the congestion benefits. In order to maximize these benefits MIT needs to make the program more universal.

Another option would be a pass that automatically enrolls all employees and students, but allows all people but Commuter Permit parkers to opt out. 15% of current LinkPass holders use less monthly value from the program than the pass actually costs them, even accounting for the 50% MIT subsidy. This points to a convenience factor that exists in both an opt-in and opt-out regime, but is likely to be significantly higher in an opt-out regime. This thesis therefore assumes that all people who have activity patterns that are 75% or more of the value of a Universal Access Pass will choose to remain in the program.

Priced at $312 annually ($26 monthly), this program would automatically enroll Commuter Permit parkers. Additionally, per Table 7-27, 36% of all employees who currently only have an occasional permit would participate, as well as 65% of employees who have neither a pass or permit. Because of pre-tax benefits and the convenience factor it would include all employees who currently use more than $13 of transit value per month. It would also include all students who use more than $20 of transit value per month. This amounts to an additional 7,625 participants. The total of 13,550 participants out of 18,191 students and employees on campus is a participation ratio of 74.5%.

Table 7-27. Opt Out Program Participation Rates

Participation Rate	Employees	Grad Off Campus	Grad On Campus	UGrad Off Campus	UGrad On Campus
Regular Parking	100%	27%	31%		34%
No Permit or Pass	65%	53%	55%	47%	47%
Occasional Parking Only	36%	42%			

As seen in Table 7-28, the program would save fewer leased spaces than the mandatory program, but not significantly so. Assuming the savings from the leased parking are immediately put back into the program, it would add an additional 7,625 employees and students with unlimited access to the MBTA, without incurring additional costs to MIT in the short term. Because the total cost of the program is only 10% less than it would be for someone to opt in to a LinkPass, the perception that this is not a "good deal" may prevail.

Table 7-28. Annual Detailed Costs And Effects Of $312 Annual Opt Out Program

	New Transit Passes	7,625
	Spaces Reduced	323
	Pass Cost	$312
	Universal Access Pass Revenue	$3,354,075
+	Subsidy Maintenance	$2,454,382
=	Total Revenue from Transit	$5,808,457
-	Total Usage Cost	$5,958,648
-	Add'l Transit Usage: Employees	$943,078
-	Add'l Transit Usage: Students	$531,817
	Total Transit Cost	$(1,625,086)
+	Lease Savings	$836,391
+	Savings from moving LinkPass holders to pay-per-ride	$518,275
+	Savings from increased employee deductions	$273,698
=	**Net Savings to MIT**	**$3,278**
	Total Increase in MBTA Revenue	**$956,620**

If these predictions do hold, it would be quite successful for MIT in the long run. Under a no growth scenario, MIT's savings increase by $300k annually by year 10, whereas in the growth scenario they increase to $1.1m annually. The MBTA sees a $950k growth in revenue in year 1, and a more than doubling of the total payments coming through MIT. Moreover, under an opt-out program, all employees who remain in the program do so by choice, so all are, by definition, strictly better off. The emissions reductions are similar to the mandatory UPass program, at 9% of total emissions from journey to work transportation, slightly reduced because the program does not encourage as much habit-forming behavior for non-drivers. In other words, if the predictions are accurate, this program achieves much of what the mandatory program achieves, without requiring participation except for those people who have chosen to have a Commuter Permit.

At this price level, an opt-in program is unlikely to see any significant additional participants vs. the current transportation subsidy regime. The price reduction is less than $4 per month against a LinkPass. Using the earlier finding of a pass elasticity of -0.6, fewer than 240 additional people will opt to purchase a transit pass at this price. Thus, an opt-in program that includes a free Universal Access Pass for drivers is most similar not to an opt-out program, but to the base mandatory pass for drivers program. The reduction in cost of the pass leads to an additional cost of $193k for MIT against that program, without increasing participation significantly against the baseline.

7.6.3 LIMITED ACCESS TRANSIT PASS

The so-called Half Pass or Limited Access Pass would allow people to opt-in to a program for a lower fee than the current LinkPass program, but have a soft cap of usage at 20 linked trips per month. MIT would monitor usage, and if a person exceeded the soft cap in two consecutive months, they would automatically be moved to the unlimited pass, at twice the cost. This would allow participation by those people who do not currently use a significant amount of transit, but use it to commute occasionally, or would like to begin using it. It provides people with an easy way to "graduate" to a LinkPass. Using rational cost behavior only those employees who use more than $10 of monthly value and those students who use more than $15 of value opt in. An additional 10% of LinkPass holders who take fewer than 20 linked trips opt-down, because the Limited Access Pass provides effectively the same benefits as a full LinkPass, but their usage patterns mean that they save $15 monthly.

Based on rational cost expectations, employee pass choice was simulated and entered into the predictive model. The results were then scaled to the number of students who opt in to the program, based on usage. As can be seen in Table 7-29, there is much less of a savings from leased parking than in other programs, but also less increase in transit usage. The program ends up being slightly net positive for MIT, mostly because MIT capitalizes on the savings from moving existing LinkPass holders who use less than the $59 of value to a MIT Pays-per-ride card. In the long run, there is an additional $200k-$260k in savings, depending on how MIT grows in the intervening years. An additional 16% of the population at MIT now has a transit pass which allows them access to zero marginal cost transit. The MBTA also sees their total revenue from MIT employees increase by 9%, and their payments from MIT increase by 16%. All employees are strictly better off, since this an optional program. The emissions and congestion reduction from this program are marginal, since for the most part it draws from the existing non-SOV commute population. This program meets MIT's and employee's goals for short run revenue neutrality and long run cost mitigation, but does much less to advance an environmental agenda than other programs. To meet these other goals, this program is best implemented in combination with either/both zero cost passes for employees who have monthly parking permits, and daily parking fees. The latter of these options is analyzed in the next section.

Table 7-29. Annual Participation, Revenue And Costs Of Student & Employee Limited Access Pass

	New Participants	3,367
	Reduction in LinkPasses	517
	Spaces Reduced	66
	Revenue from Program	$513,006
+	Lease Savings	$169,774
+	Savings from moving LinkPass holders to pay-per-ride	$466,448
-	Transit Cost: Employees	$378,332
-	Transit Cost: Students	$764,233
=	**Net Savings to MIT**	**$6,663**
	Total Increase in MBTA Revenue	**$676,117**

7.7 Parking Price Programs

Chapter 5 showed that in FY11 moving to a $4 daily parking rate from the currently monthly system will not result in an increase in costs for any employee. It will, however, result in a reduction in revenue for MIT. Actual revenue loss will be equivalent to the difference between the daily charge multiplied by the number of days people actually park, and the revenue MIT would receive if they continued the monthly program. That is, it eliminates the revenue from the over-allocation of permit holders to parking areas. There is another potential revenue loss, from those people who have Occasional Permits, but park more than 8 days per month. By policy these people pay $10 for each day they park over 8 days in the month, rather than $4. By practice, this additional charge is not imposed. There is the theoretical risk that these people will in fact park more because of the removal of this potential penalty. However, the data shows that the 8 day limit does not prevent Occasional Parkers from parking more than 8 days per month. There is no noticeable drop after 8 days – the distribution across days is smooth, and skewed to the lower end of the spectrum.

Thus the effectiveness of the program for the Institute will be found in weighing the imposition of daily costs, and thus potential savings from not driving, against the revenue loss both from those non-drivers, and from the fact that empty spaces no longer generate revenue. Because of increased variability between days due to the more incentives to optimize the travel pattern for the day's activities, weather, etc., there will also need to be more spaces reserved for high demand days. Thus far savings calculations have been based on MIT being able to turn 80% of the reduction in drive trips to a reduction in spaces; 20% are kept in order to reduce congestion issues from day-to-day variability. For daily parking the assumption is that 70% of the reduction in parking demand will result in savings.

There is one final complication. Only 70% of parking spaces at MIT are gated. Those spaces without gates cannot have their usage measured, and thus cannot move to a daily rate. Recall that earlier those people were removed from the model sample. Thus, predictions need to scale back both demand and revenue reductions from the model by 70%.

As is evident from Table 7-30, $4 daily parking redistributes slightly fewer than 40% of the employees who currently park everyday, or almost so, into options where they park less often. However, there are very few people who end up moving to options where they do not park at all, as expected. There are also small increases in transit usage, to make up for these trips. These results reinforce the rationale for changing policy options asserted throughout this thesis. The single mode man does not describe a substantial minority of the community, and if given the proper incentives, may not describe a significant portion of the majority. Daily pricing removes the monthly commitment to parking, and thus the incentives to maximize its use. It is important to reiterate that in these results fully 60% of employees who drive everyday change their behavior not one bit. As expected, not everyone is able to, or desires flexibility, but 40% of employees will respond to the flexibility by voluntarily changing their behavior in a green direction.

Table 7-30. Distribution Of Changed Behavior By Employees, Daily $4 Parking Charge Replaces Monthly Parking Permits

	Transit CEQT*					
Parking CEQT*	**0**	**1 -5**	**6-10**	**11-15**	**16-20**	**Total**
0	197	-51	-40	-23	-54	29
1-5	189	85	60	65	121	521
6-10	62	18	61	31	41	212
11-15	-30	49	6	7	8	40
16-20	-555	-193	-49	-5	0	-802
Total	-137	-92	38	75	116	

* See Appendix 7 for more detail on the ratio between CEQT and trips / parking events.

As shown in Table 7-31, most of the reductions in driving trips lead not to increases in transit trips, but increases in ridesharing, walking and biking, and other trips that are not recorded. Inasmuch as people do move to transit there is an increase in the number of transit passes sold, and thus an increase in subsidy costs for MIT.

Table 7-31. Mode Share Changes Of Daily $4 Parking Vs. FY11 Baseline

	Transit	**Drive**	**Other**
% Who Use Mode	1.6%	-0.3%	5.5%
Total Monthly Trips	3,093	-10,659	6,280
Mode Share	2.5%	-6.9%	4.4%
Trips / User / Month	0.24	-2.70	0.49

Including the savings from leased parking, the program is net positive for MIT. This is very much affected by the twin assumptions that only a total of 70% of the change in trips is actual, and that MIT will only be able to capitalize on 70% of that change to reduce leased parking. Costs for students have not been projected, under the assumption that the current program for students is maintained.

As can be seen in Table 7-32, $4 daily parking in FY11 meets MIT's goals of short-term loss aversion, and no negative effects to employees. Both because of the spaces saved, and because of the reduction in parking demand for new employees, over ten years there is an additional $300k-$900k annual savings from avoiding building new parking depending on MIT's growth. Thus it also meets long run cost containment goals.

Table 7-32. Revenue And Cost Effects Of $4 Daily Parking Vs. FY11 Baseline

	New Transit Passes	191
	Spaces Reduced	262
	Revenue from Parking if Lots Full	$3,697,152
-	FY11 Parking Revenue	$3,495,443
-	Daily Empty Spaces	$295,772
+	Maintenance of Revenue from Ungated Lots	$28,219
-	Lost Revenue from policy	$405,775
=	Net Parking Revenue Loss	$(471,619)
+	Lease Savings	$678,521
+	Savings from moving LinkPass holders to pay-per-ride	$0
+	Savings from increased employee deductions	$0
-	Add'l Transit Usage: Employees	$79,195
=	**Savings to MIT**	**$206,902**
	Total Increase in MBTA Revenue	**$79,195**

Daily parking is less successful in its ability to affect Cambridge and MBTA goals. It does not increase revenues for the MBTA in a significant manner. The revenue increase is 1% of MIT's annual payments to the MBTA, and is smaller than the annual growth that results from the hiring of new employees. The reductions in emissions from journey to work transportation are on the order of 6%, but there is less upside than for transit pass programs. Because the policy does not affect the cost of transit, only the daily cost of parking, it does not contain any long term incentives to move to more transit accessible areas and thus reduce non-commute auto usage. The congestion effects are also somewhat modest.

If pricing is variable depending on the type of lot, additional short-term revenue can be raised, but this may come at the cost of MIT's desire to retain equitable opportunity to benefits. If there is a daily $2 surcharge on parking in an underground lot, MIT can raise an additional $280k from the current underground parking lot, the Stata Garage, and an additional $160k in FY11 from the new Sloan Garage. This is unlikely to decrease net demand for parking on campus; current people who park in the Stata Garage would have the option to downgrade to a lower demand lot at $4 per day. However, those people who did pay the additional cost would be aggrieved, and those people who moved to a lower demand lot would believe the policy was punishing. Thus, while it would increase revenue, it might come at the cost of employee morale. The perception of less expensive transit that a coincidental Mobility Pass program would provide may mitigate these factors somewhat.

Alternatively, MIT could reduce rates at lots where there is significant empty space. This would allow more flexibility to allocate spaces in higher demand lots. Rather than increasing prices on anyone, it would allow people the option to mitigate the cost of parking via a longer final leg of the trip. There are approximately 200 spaces on campus that are empty on most days because they are in the far west portion of campus. A $2 daily rate would likely result in a gross $80k reduction in parking revenue. This cost would be mitigated by MIT's ability to increase allocation to other higher demand lots on campus. However, this sends a perverse signal about MIT's willingness to continue their subsidies for parking.

7.8 Mobility Pass Programs: Combined Parking And Transit Benefits

Each of the programs evaluated thus far effect the demand for parking only on one side of the equation. The transit pass programs increase the number of people who have access to zero marginal cost transit, and thus "pull" people away from driving to MIT. Daily parking removes zero marginal cost parking from most of MIT's population without affecting total cost for employees, and thus is a "push" from driving. Each of these programs can be effective in decreasing demand for parking, and meet many of the stakeholder conditions for an effective program. None of them are optimal for all stakeholders. The following section shows that these programs are more effective at meeting goals in combination than they are separately. The results are not simply additive.

This section evaluates two separate programs, based on short-term implementation viability. The first program looks at a combination of policies that focus on continuing the unbundled approach to transportation benefits; a $4 daily parking rate and a $15 Limited Access Transit Pass. The second program is composed of policies that give more incentive for people to bundle benefits, and decreases costs for existing transit users. This includes a $24 opt out Universal Access Pass, and a $3 daily parking rate for employees. The cost for both programs is projected against the baseline costs for FY11.

7.8.1 Mobility Pass Option 1

Whereas with the separate $4 daily parking charge, there was an increase in people who chose neither transit or parking at MIT, the Limited Access Pass pulls a net of 2,850 students and employees into the program. The increase in transit usage is greater than the additive change of the two programs separately, as is the decrease in drive usage. Just under half of all students and employees effectively have zero marginal cost transit under this program.

As can be seen in Table 7-33 and Table 7-34, the savings from this policy in the short term are just over $20k annually. By ten years out the decrease in drive mode share, and the decrease demand from current drivers results in an additional $300k-$1.3m in annual savings, depending on the growth scenario over those years. Thus, this iteration of the Mobility Pass meets MIT's long and short-run cost recovery goals, while remaining completely optional. It increases the number of people on campus with zero marginal cost transit by just over 16% of the population. Total emissions savings are 12% of current emissions from commuter transportation. Local congestion reductions may be relatively achievable, given that there is little increase in people being dropped off. The MBTA sees an increase of 8% of their current revenue from MIT students and employees, and 13% from MIT's current MBTA payments.

Table 7-33. Mode Share Changes From Mobility Pass Option 1 Vs. Baseline

	Transit	Drive	Other
% Who Use Mode	12.1%	-2.0%	-3.7%
Mode Share	14.6%	-10.7%	-4.0%

Table 7-34. Revenue And Cost Effects Of Mobility Pass Option 1 Vs. FY11 Baseline

	New Transit Passes	2,850
	Spaces Reduced	412
	Transit Pass Revenue	$513,006
-	Add'l Transit Usage: Employees	$425,856
-	Add'l Transit Usage: Students	$688,186
	Total Transit Cost	$(1,114,043)
	Revenue from Parking if Lots Full	$3,697,152
-	FY11 Parking Revenue	$3,495,443
-	Daily Empty Spaces	$295,772
+	Maintenance of Revenue from Ungated Lots	$125,683
-	Lost Revenue from policy	$517,575
=	Net Parking Revenue Loss	$(485,956)
+	Lease Savings	$1,066,259
+	Savings from moving LinkPass holders to pay-per-ride	$518,275
+	Savings from increased employee deductions	$35,910
=	**Net Savings to MIT**	**$20,446**
	Total Increase in MBTA Revenue	**$595,768**

7.8.2 Mobility Pass Option 2

The second option substitutes an opt-out Universal Access Pass for the opt-in Limited Access Pass. People with monthly permits are not permitted to opt-out. However, a reduction in the daily cost of parking to $3 means that they are no worse off under this program that would be with a $4 daily rate. This program allows unlimited, rather than limited access to transit, and ensures that all people who drive to MIT have the option to take transit on a zero marginal cost basis. Because of the reductions in parking achieved from the combined program, the pass price is cheaper than it was for the opt-out program only. Rather than $312 annually ($27/month), the pass can be priced at $288 annually ($24/month), and still break even in the short run. This increases the percentage of people who choose not to opt out, so that a total of 77% of employees have access to zero marginal cost transit, as shown in Table 7-35.

Table 7-35. Participation In Mobility Pass Option 2

Population	Current Passholders	New Passholders	Total Passholders	Participation Rate
18,191	5,925	8,006	13,932	77%

As shown in Table 7-36, transit usage increases significantly against the business-as-usual scenario, both among new and existing riders. Only slightly fewer people drive, but those who do drive, drive less. The model may overestimate the reduction in people who neither take transit nor drive. Therefore the cost estimates err overly on the expensive side in this policy scenario.

Table 7-36. Mode Share Changes For Mobility Pass Option 2 Vs. Baseline

	Transit	Drive	Other
% Who Use Mode	19.9%	-1.0%	-7.2%
Mode Share	18.8%	-12.7%	-6.2%

Combined, the program is revenue neutral to MIT in the short term, as seen in Table 7-37. It increases MBTA revenue by 15% over the total current payments to the MBTA by MIT students and employees, and 20% over MIT's payments. Moreover, rather than option 1, where approximately 55% of those payments are still from individuals, in this case over 85% of payments are routed through MIT. This achieves an additional 33% subsidy by the federal government for those people. The transit usage was formerly purchased with after-tax dollars is now paid through pre-tax contributions. This amounts to an almost $800k federal subsidy to employees for the program, and more than $280k in additional savings for MIT, since they no longer pay FICA on those dollars.

Table 7-37. Revenue And Cost Effects Of Mobility Pass Option 2 Vs. FY11 Baseline

	New Transit Passes	8,007
	Spaces Reduced	535
	Pass Cost	$288
	Transit Pass Revenue	$4,012,273
+	Subsidy Maintenance	$2,454,382
=	Total Revenue from Transit	$6,466,655
-	Total Usage Cost	$5,958,648
-	Add'l Transit Usage: Employees	$1,021,346
-	Add'l Transit Usage: Students	$575,954
	Total Transit Cost	$(1,089,292)
	Revenue from Parking if Lots Full	$2,772,864
-	FY11 Parking Revenue	$3,495,443
-	Daily Empty Spaces	$221,829
+	Maintenance of Revenue from Ungated Lots	$283,322
-	Lost Revenue from policy	$441,454
=	Net Parking Revenue Loss	$(1,102,540)
+	Lease Savings	$1,385,815
+	Savings from moving LinkPass holders to pay-per-ride	$518,275
+	Savings from increased employee deductions	$282,266
=	**Net Savings to MIT**	**$(5,476)**
	Total Increase in MBTA Revenue	**$1,079,025**

In the long run this results in an additional $400k to $1.4m in savings from parking depending on MIT's growth. While the program is slightly more expensive than the first Mobility Pass option in the short term, by ten years out it saves more money on an annual basis. The commuter emissions savings are also 14%, or more than 20% higher than the first option. There is more upside potential for these savings because more non-commute trips move away from the auto. Congestion reduction is similarly 20% higher than Option 1. Mobility Pass Option 2 enrolls more people, provides employees with cost savings, and produces more benefits. However, it is more coercive, and in the short term is slightly more costly, although it is still revenue neutral against the FY11 baseline.

7.9 Summary Of Policy Options

This chapter has shown that MIT's policy of subsidizing transit 50%, while generous, does not offset the increase in auto commuters caused by its subsidies of parking. This chapter evaluated a number of policies that are revenue neutral to the Institute, given the reinvestment of savings from leased parking in the short term. This turns into savings from not constructing additional underground garages in the long term.

1. A mandatory Universal Access program would significantly increase transit usage, and decrease transportation emissions, but the mandatory nature would result in up to 40% of the population of students and employees seeing increased costs in the short term, thus reducing support.
2. Providing full time parkers with a free LinkPass would decrease the use of parking sufficiently to be revenue neutral for the Institute, but may engender perceptions of unfairness from other employees
3. An opt out program priced at $26 would reduce the negative associations of the prior programs, but to reach revenue neutrality would make those people who have monthly parking permits worse off.
4. If MIT instead offered a Limited Access Pass, it would attract participation by a significant population who do not use enough transit currently to purchase a LinkPass. However, this program does not significantly reduce MIT's costs and emissions due to commute auto travel.
5. A program based purely on introducing daily marginal price parking at MIT would encourage mode switch, and result in cost savings for MIT, but would have significantly less positive environmental consequences
6. Mobility Pass Option 1 (combining the Limited Access Pass and daily parking) capitalizes on the saving inherent in both programs.
7. Mobility Pass Option 2 (combining an opt out Universal Access Pass with daily priced parking) can be designed so that everyone at MIT sees cost savings, the Institute sees significant cost savings in the long run, and emissions reductions are even higher than a mandatory pass.

These programs include student costs, for equitable reasons, but the emissions reductions and cost savings from students are negligible because they mostly do not own cars or drive to campus. At Universities across the country students are the impetus for Universal Passes. At MIT, the reverse is true.

8 CONCLUSIONS

The first portion of this thesis established that the myth of the single mode man manifests itself in the samples used to model travel behavior and the policies put in place by employers and at the federal level. These policies are based on a myth which has validity for a majority of commuters, but is not valid for a substantial minority. The myth reinforces and perpetuates itself. Federal transportation fringe tax benefits and employer subsidies incentivize employees to be monomodal. Federal policy encourages employers to subsidize parking in lieu of providing monetary compensation. Single mode commute trips lead to less variability in mode choice for all trips. This can increase total SOV VMT, and therefore have negative environmental and congestion consequences. Therefore it is important to understand the potential of variability in mode choice if we want to design incentives that not only appear to provide incentive to motivate choices with beneficial congestion and pollution reduction consequences, but actually are effective.

Employer parking subsidies promote driving and parking. These subsidies makes parking more expensive to provide, and also result in more emissions. They also creates a constituency to maintain and increase those subsidies. At the same time, less land for inexpensive surface lots means that the cost of building and operating parking is constantly increasing above the rate of inflation. Local government incentives to build parking underground may reduce the negative urban design aspects of lots and aboveground structures, but also encourage the construction of structures that become permanent investments. These permanent investments increase the subsidies required for parking, which in turn make it more difficult for employers to contemplate ending them. This is a destructive feedback loop that results in more people driving and parking than otherwise would, higher emissions and congestion, employers beset with increasing costs with few attractive mitigation measures, and less transit ridership. Cities are worse places to live because the belief in the universality of the single mode man leads to policies predicated on that myth which perpetuate the pattern.

Chapters 6 showed that employees at MIT are more flexible than the policies predicated on the single mode man myth imply. Even in the face of economic disincentives, many employees continue to use multiple modes to commute to work at MIT. Younger people are more flexible and more transit oriented, but there seems to be little to no effect of income or position on multimodal behavior. Moreover, people are becoming increasing multimodal over time.

Policies that remove the disincentives for multimodal behavior break the feedback loop of ever-increasing parking subsidies, congestion, and emissions. By doing so they can reduce the inefficiencies of the current system and provide monetary gain to employees, employers, and transit agencies. Policies that encourage multimodal behavior are more sustainable, both environmentally and monetarily.

Chapters 4 and 5 outlined the constraints placed upon any new programs by the constituencies the old regime has created. Federal transportation fringes make benefits a relatively inexpensive employee recruitment and retention measure in an increasingly dire economic climate. MIT may perceive that it can not make even minimal investments in policies that decrease parking costs in the long-term. Benefits signify more than their total dollar value; they are also a stand-in for an employer who is concerned for their employees' health and welfare. This meaning is increasingly in conflict with the environmental missions of large institutions; the parking benefits they provide increase emissions. To counteract this, places like MIT have increased their transit subsidies in the last 2 decades. Chapter 8 shows that these are not offsetting policies. Because they are usually much higher than transit subsidies, parking subsidies do more to encourage driving than transit subsidies do to discourage it. Combined, they disincentivize non-motorized and shared commute options. Employers are paying twice, and are still not able to maintain the status quo in environmental impact as they grow. Employees are worse off than they would be if they received these benefits with more flexibility rather than in kind.

Chapter 3 showed that innovative programs run by transit agencies can help break this cycle. Universal Access Passes provide zero marginal cost transit passes across all employees at a job site. They do so without increasing costs for employers. Across the country these programs have been put in place at Universities, and are increasingly being spread to employers. Smartcards allow transit agencies to track fares on a per-use basis, reducing the reliance on "guesswork" that hampers some of the existing programs. This guarantees that transit agencies fully recover revenue streams for existing riders, and that full fares are collected from all new riders.

When employers and transit agencies join forces, they can design programs that meet common goals. At the University of Washington they have reduced parking demand by combining parking and transit benefits programs into a single transportation benefits program. They have aligned the economic incentives for their employees' commutes with their own economic and commute trip reduction goals. This has significantly increased transit usage by students and employees, and allowed the local transit agency to provide better service to the campus.

Chapter 7 used these lessons to design a series of similar programs for MIT. Each of these programs, the costs of which are shown in Table 8-1, was designed to fit within the political and cost constraints of the Institute. These policies are cost neutral in the short term, cost saving in the long run, revenue neutral or positive for the MBTA, and reduce congestion and emissions. They fit into the meanings that benefits have accrued, and encourage rather than mandate participation. None of these programs may be an exact fit for MIT, or for other large institutions or companies. But, each of them utilizes the building blocks that allow creative program designs that encourages flexibility: (1) marginal cost parking pricing, (2) compensating the transit agency on a per-ride rather than pass basis, and (3) cost redistribution. These benefits are not unique to MIT. Encouraging the flexible use of transit through well designed programs that combine parking and transit benefits into a single package can be a profitable and socially useful endeavor wherever parking is subsidized and transit is accessible. MIT is a useful demonstration of the concepts and designs these programs can take, which makes use of the wealth of data available to be analyzed.

Table 8-1. Comparison On Mobility Pass Option

		Mpass Opt 2	Mpass Opt 1	Upass Opt Out	Daily Park
	New Transit Passes	8,007	2,850	7,625	0
	Spaces Reduced	535	412	323	262
	Annual Pass Cost	**$288**	**$180 Half Pass**	**$312**	
	Net Program Revenue	$508,007	$513,006	$(150,191)	
-	Add'l Transit Usage: Employees	$1,021,346	$425,856	$943,078	$79,195
-	Add'l Transit Usage: Students	$575,954	$688,186	$531,817	
=	Total Transit Cost	$(1,089,292)	$(1,114,043)	$(1,625,086)	
	Daily Parking Charge	**$3**	**$4**		**$4**
=	Net Parking Revenue Loss	$(1,102,540)	$(485,956)		$(471,619)
+	Lease Savings	$1,385,815	$1,066,259	$836,391	$678,521
+	Savings from moving LinkPass holders to pay-per-ride	$518,275	$518,275	$518,275	
+	Savings from increased employee deductions	$282,266	$35,910	$273,698	
=	**Net MIT Savings**	**$(5,476)**	**$20,446**	**$3,278**	**$206,902**
	Increase in MBTA Revenue	**$1,079,025**	**$595,768**	**$956,620**	**$79,195**
	Annual Savings 10 years out	$857,737	$725,106	$645,221	$655,108
	Emissions reductions from Commute travel	14%	12%	9%	6%

While the cost savings are similar for these programs, there is clear advantage seen in Table 8-1 in emissions reduction, and similar reductions in congestion for the Mobility Pass Options, particularly Option 2, which includes an opt-out Universal Access Pass. While neither of the mobility pass options reduce the number of people who ever drive to MIT in Figure 8-1, both programs significantly reduce the total number of trips to MIT, as seen in Figure 8-2. Mobility Pass Option 1 uses the price of parking as more of a lever, without as significant an expansion of transit benefits as option 2, and thus sees more of these drive trips moving to rideshare and other non-SOV, non-transit modes. Option 2 sees a greater increase in the share of trips via transit and a greater movement away from driving, thus resulting in more emissions and congestions reductions.

Figure 8-1. Percent Of Employees Using Mode, Mobility Pass Options Vs. FY11 Baseline

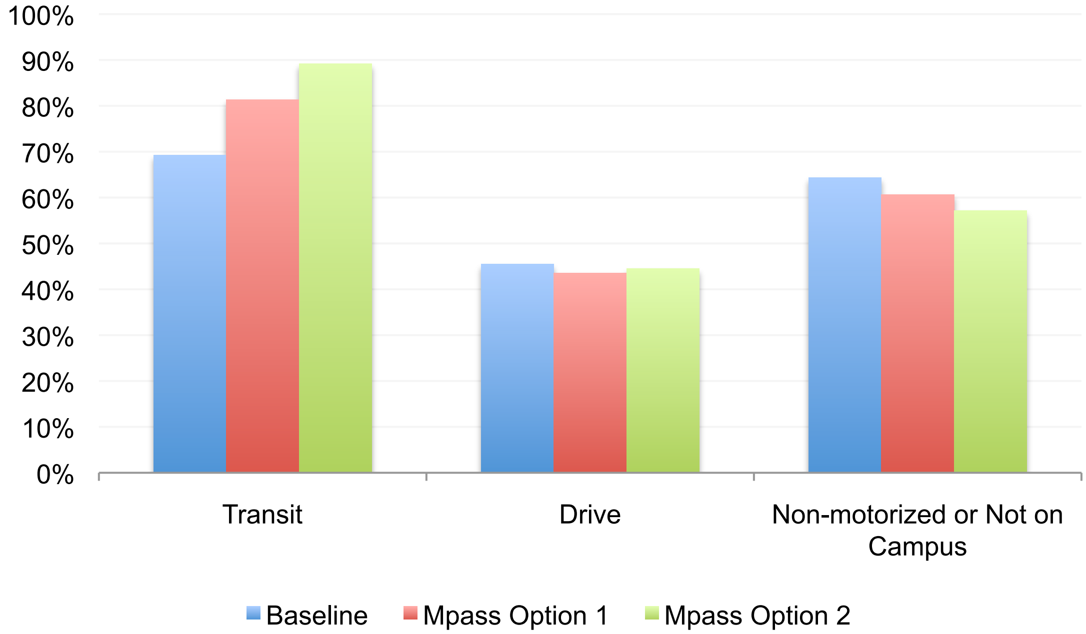
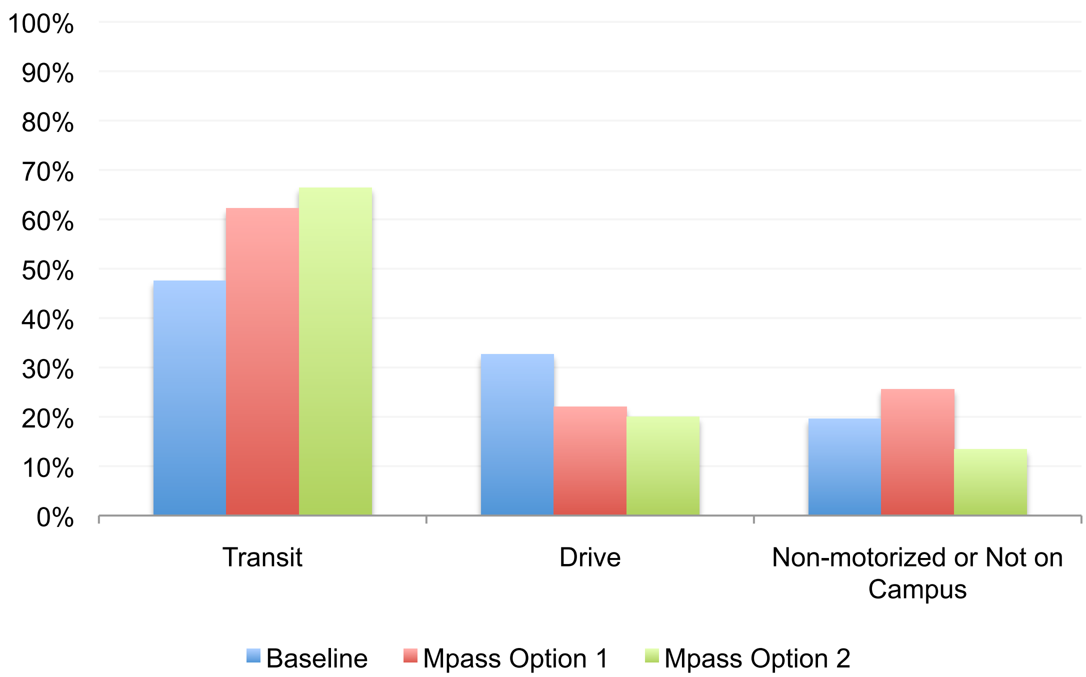


Figure 8-2. Percent Of Trips Using Mode, Mobility Pass Options Vs. FY11 Baseline



The constraint of cost neutrality in the short run imposes higher costs on employees and students. Cost neutrality decreases the viability and effectiveness of the programs that significantly reduce costs and emissions in the long run. Fewer parking spaces are saved by these changes than the 1,000 additional daily drivers

Chapter 7 shows result from the parking subsidies currently in place. For example, the evaluation of the opt-out Universal Access Pass program priced at $26 monthly determined that it will result in a participation rate higher than 70%. On a purely rational basis, the choice architecture has changed, and thus these predictions will be accurate. However, moving to a program that provides only an additional 10% discount over current LinkPass pricing may not be perceived positively. People may not act in their own economic benefit, and thus increase costs for MIT, because they do not perceive that MIT is "doing their part." That is, this thesis has assumed a rational basis for action. But it must be acknowledged that people do not always act as strictly economic maximizers. Perceptions of unfairness and inequity can cause people to act differently than rational models predict. Programs that absorb some of the costs in the short term can increase positive perceptions, and by decreasing the costs encourage more behavioral change, thus also providing higher payoffs in the long run. Each $1 reduction in MIT's charge for an opt-out Universal Access pass decreases revenues by approximately $165k. This may be the marginal cost of success.

Throughout this analysis the basic rule of thumb is that the more people on zero marginal cost transit passes today, the more savings tomorrow. Inasmuch as these programs are perceived as reducing the costs of transit access, they may also be quite popular. Changing the architecture of choice need not be met with resistance if it is designed carefully and creatively. Program acceptance is assisted by Federal transportation fringe benefits. By moving people from paying for transit with after-tax dollars, to paying with pre-tax dollars, employees can save 30%+ of the cost of transit access. Furthermore, each dollar an employee spends on transit through their employer reduces employer's real costs (FICA payments) by 7 cents.

8.1 Student Options

Chapter 7 concluded that a program without an opt out provision would likely be untenable because of opposition from employees. While this is likely true for employees, it is less accurate for students. Chapter 3 showed that throughout the country students have voted overwhelmingly to impose mandatory fees for Universal Access programs. This requires both a clear explanation of the benefits of the program, and a base of students who support such a vote. The initial discussion of a Universal Access Pass at MIT 5 years ago did not reach the stage of a student vote, nor was there a concerted effort to win support, in part because the MBTA was not ready to proceed with a practicable mechanism for implementation. Times have changed. Environmental consciousness has increased among students. The introduction of the CharlieCard has removed obstacles to implementation. There may be an opportunity for a Universal Access Pass to gain significant support among students. If this was the case, it could be priced at $150 per semester, and include year-round access to the entire MBTA system, including commuter rail. Bamberg & Schmidt (2001) showed that the public discussion of similar programs in fact leads to increased support and usage of transit, especially among those people who do not initially support the program. Any program needs to be discussed, not only announced.

The programs proposed in Chapter 7 included the cost of increased student usage of transit, but also the revenue from those students. Removing both that gross revenue and gross cost from those programs could remove up to $500k in net costs annually, depending on the proposed program. Handling students separately reveals the true value of these programs for employees.

8.2 Smartcard Opportunities

The MBTA's introduction of SmartCards provides opportunity to design a Mobility Pass so that the distinction between opt in and opt out programs is blurred. This thesis has proposed integrating the CharlieChip into all of MIT's ID cards. Because the MIT ID is required for access to buildings and offices on campus, as well as athletic and other facilities, this measure would reduce the number of people who buy a subsidized pass through MIT, but give it to their spouse, friend, or child. It also provides an opportunity for more innovative choice architecture. For example, the card could be activated for everyone, but not billed until the student or employee uses it. In this case, the first use would be an assertion by the student or employee that they wanted to join the MIT subsidized pass program. If combined with the proposed Limited Access Pass, the initial charge would be $15, until the cardholder uses it for 20 or more linked trips in the month, after which the charge would be $29.50, or whatever the Universal Access Pass price is.

This would provide all students and employees with an active card in his or her wallet or purse, and remove the disintermediation that currently exists between signing up for the program and using transit. It would also effectively create best-value pricing for all students and staff. If they did not use the card in a month, they would not be charged for it. Program participation would be complete, but only active users would be charged. This would eliminate some of the savings that MIT could expect to see from moving LinkPass holders to a pay-per-ride system, but might also increase the congestion and emissions reductions benefits, as it would remove a threshold for participation.

8.3 Managing Best Value

This thesis has proposed a program, based on prior negotiations with the MBTA, which requires active management by MIT in order to receive the best value from pay-per-ride pricing. While it is theoretically possible to use this to minimize costs for MIT, in practice it would be more difficult. Identifying those current LinkPass holders who use less than $59 of fare value from the card requires a process of experimentation, or self-selection. For new employees it is somewhat easier, as all people can initially be placed on the pay-per-ride program, and only moved to payment by MIT to the MBTA at the LinkPass price when they show that they use more than the pass value on a monthly basis. An automatic monthly cap is likely to run up against the MBTA's concerns with being perceived as providing MIT with a better deal than is accessible to the general public. However, both the administrative burden on MIT and the MBTA's justifiable concerns can be relieved programmatically.

The MBTA could automatically cap fares – provide best monthly value – at a premium to the LinkPass price. This would allow them to recoup additional revenue from those people who use more than the $59 value of the card. MIT would then be paying a premium to receive an additional benefit. 58% of LinkPass holders at MIT use more than a 10% premium of $65 of fare value per month. Therefore this program would cost MIT an additional $221k annually. However, it would allow MIT to automatically see the $518k in annual savings from LinkPass holders using less than the $59 value. The MBTA would be charging a risk premium on top of the monthly pass cost in order to insure against less monthly usage than the pass value. This best-value pricing could also be an optional component for MBTA's pass offerings for their entire customer base, not just MIT. MIT would then be the pilot for the entire region for best-value pricing. Calculating exact pricing requires a more in-depth look at systemwide usage of LinkPasses, rather than the limited and likely non-typical subset of MIT employees.

8.4 SYSTEMIC PROBLEMS REQUIRE COORDINATION

Transportation fringe benefits give employers an incentive to compete on parking price. In most of the country employers fully subsidize parking spaces. In Cambridge and Boston it results in highly subsidized parking. As seen in Chapter 8, removing these subsidies would reduce MIT's costs significantly, and have large congestion reduction and emissions benefits. It is unrealistic to expect that MIT could do so unilaterally, without significant costs to employee retention and recruitment. This is a systemic problem.

Cambridge could require this lack of subsidy policy as part of their TDM programs. Unfortunately, since MIT has essentially carved out an exception from Cambridge's mitigation measures by stabilizing the amount of parking on campus, it would not immediately apply to MIT. Alternatively, Cambridge could coordinate the removal of these subsidies by requiring all employers over a certain size to provide only market rate parking. Finally, Cambridge could require that parking, which is essentially rented from MIT by employees, be unbundled from employment. This could take the form of a mandate that MIT and other large employers remove themselves from the parking business. This would require those employers to sell their parking facilities to outside vendors.

In essence, MIT has already begun to take this last alternative. It employs a third-party to run its parking facilities. Instead of paying this vendor to provide operational services, MIT would bid out its existing parking to a third-party, who would have the right to charge a market price for parking. Payments would then be made by MIT, through employees, to separate parking companies. These companies would run a for-profit business. This would retain the tax benefits of parking, but ensure that spaces were priced at market levels. MIT would likely receive money from selling these assets, since they have already paid for the capital cost of the parking spaces. It would not prohibit MIT from incorporating underground spaces into new buildings, but it would require that they be priced appropriately. Many cities have required that parking spaces be unbundled from the cost of condominiums. This proposed policy by the City of Cambridge would require that parking that is "rented" be fully unbundled from employment, as opposed to its current partial bundling.

The prisoner's dilemma is a classic game theory problem. Each actor has incentive to choose to stay mum upon interrogation if they know the others will, but will be punished if others do not. Coordination is the only way to avoid mutually assured destruction. Parking subsidies have increased because of lack of coordination. But there is another way out. The prisoners can make the prison a place to better themselves; they can use the assured outcome to their advantage. The dollars used for parking subsidies could be reallocated to compete on other tax-privileged fringe benefits that do not have negative environmental and cost consequences. At its essence, the result is a parking cash out program without the implicit costs of subsidizing those people who do not currently park on campus. Coordinated action by employers, in cooperation with the City of Cambridge, may be able to avoid the cost issues that make parking cash out untenable in high transit mode share areas.

However there are two significant issues with this proposal. For one, Cambridge is in competition with other cities and areas (for example the Route 128 corridor in the Boston metropolitan area) for growth. If this program made employees unhappy (if employers did not raise their total compensation), it would make it harder to hire within Cambridge, and thus make it a less attractive place for employers to locate. Additionally, MIT is in competition not only with local universities and other large institutions for Faculty and staff, but also with other national and global institutions. Inasmuch as these institutions offer cheap parking, it may still be an expected benefit at MIT, and thus this policy could put MIT at a disadvantage, if MIT did not raise its non-parking compensation package. While regulatory measures may be promising, the "carrots" proposed in this thesis are more immediately able to be implemented.

8.5 Extending the Mobility Pass Across Employers

The current funding crisis for the MBTA is an opportunity for the Mobility Pass. MIT's high subsidies for parking are not unique among Boston area employers. Neither is the imbalance between transit and parking subsidies. The conditions which make the Mobility Pass a nexus of action to reduce employer costs commensurate with decreases in emissions and congestion for cities and ridership for the MBTA are prevalent across major institutions in Boston. The question is: how can the MBTA capitalize on this situation to increase ridership? Increasing the reach and scope of employer programs can help mitigate the effects of fare increases. Employers have the opportunity to be perceived as the champions of their employees by increasing subsidies to offset any fare increase. Inasmuch as employers act on these incentives, the effects of fare increases are reduced in scope. Moreover, fare increases are often commensurate with changes in the fare structure. This allows the MBTA to ensure that their riders are not purely "losers." Changing the fare structure to allow riders to mitigate those increases can result in increased revenue for the MBTA while lessening dissatisfaction.

One way that the MBTA may be able to mitigate any fare increase is by creating a "best value" monthly pass rather than simply increasing their monthly pass fares across the board. This pass would be priced at a premium to current monthly passes, and would cap the cost at a total monthly price higher than the pure monthly pass cost, but still deduct individual fares. On those months where people use less than the cap, they would save money, while guaranteeing they would never spend more than the monthly cap. In essence, this would transfer the risk of monthly usage above the cap from the MBTA to the individual, and the risk of usage below the cap from the individual to the MBTA. If priced correctly, it could increase revenues, while creating the perception that the MBTA is using the CharlieCard technology it has rolled out in the past two years to offer a "better deal" to their riders.

In combination with a best value card offered to the public on an individual basis and to employers on a group basis, the MBTA may be able to draw on federal Congestion Management and Air Quality Improvement Program (CMAQ) funding to encourage employers to provide Universal Access Passes to their employees. These funds would not pay for existing riders, but would only be used to pay for the expected increase in ridership due to the extension of zero marginal cost transit to the entire employee base. Similar funding was used by King County Metro Transit (KCMT) to increase the attractiveness of their FlexPass program. At KCMT, employers have continued to participate after these funds have been exhausted. These changes could provide a temporary funding source that would grow the program over the short term, and decrease emissions. This would be both within the spirit and the letter of CMAQ funds. MIT's transit pass subsidies have increased revenue in a greater proportion than they have increased ridership. Creating a widespread program that establishes the principles of zero marginal cost transit across employers becomes a benefit that is difficult for employers to cease. These incentives encourage employers to compete on transit benefits, both because the benefit is relatively cost effective due to federal transit benefits in combination with CMAQ funds, and because other employers are doing it. In other words, there is a positive feedback cycle from Universal Access Pass programs that can work to both employers and the MBTA's advantage, and thus result in regional emissions and congestion decreases.

8.6 Areas For Improvement & Further Research

There are ample opportunities for extending and improving this work.

- **Travel Diaries**. This research would benefit significantly from a more accurate source of recording transit trips. For example, trip diaries would permit recording of actual mode usage, and allow better categorization of trips into commute and non-commute. This would allow for more exact cost estimates. It would likely also depress the upward bias in trip inflation.

These surveys need not be filled out by the entire sample. A subset would allow proper scaling for the remainder of respondents.

- **Transit Usage Data**. Even more accurate would be actual transit usage data from the MBTA. Given that each card distributed to an employee who uses MIT services is uniquely identified, it should be possible to create an optional entry field in the MIT survey while retaining anonymity. This would allow resaearchers to assess the risk premium of the monthly pass more accurately. If those employees and students who do not purchase a monthly pass through MIT were allowed to enter their CharlieCard or CharlieTicket identification number, researchers could obtain aggregate usage data to measure actual trips, and thus better determine Mobility Pass costs. A relatively small subset would allow more accurate estimates of usage for the entire sample.

- **Stated Preference Data**. This thesis has based estimated mode switch on the differences in behavior between existing employees and students, taking into account numerous explanatory factors. This allows for propensity to change behavior based on similarities to other respondents, but does not consider individual propensity to change, beyond the limited subset of people who have in fact switched modes. To counter this lack, a supplemental survey could present a number of options for possible programs in a structured format. Combining this stated preference data with revealed preference data would allow more accurate predictions of mode switch.

- **Model Improvements**. No model is perfect. Numerous additional variables could be incorporated in the model, by merging sample data census data, or by expanding survey questions. Income, home value, household constraints, and lifecycle indicators would all likely prove to be significant additions to the explanatory power of the model.

- **Model Techniques**. As explored in Appendix 7, a discrete continuous model, contingent on more accurate data sources, would permit the use of continuous variables to describe trip choice. This would allow more accurate predictions of mode switch based on changing conditions. Jointly modeling the benefits choice with the choice of trips would remove an additional sub-model from this thesis' methodology, and remove a series of assumptions about "rational" behavior.

- **Incorporating Location Choice.** Inasmuch as the long term effects of transit subsidies affect the location of residences, incorporating this choice into the model in combination with the choice of benefits and trips by mode would allow more accurate predictions of long term changes, especially for significant subsidy changes.

- **Studying Implementation**. The predictions made in this thesis are based on rational assumptions, and in line with results presented from past employer and university programs. This thesis has asserted throughout that the case of high transit mode share areas is different. Without actual results, this is only an assertion. Whatever trial programs do eventually move forward at MIT should accompanied by data transparency, so that actual results can be compared to the predictions of this thesis.

- **Survey Data Analysis**. The 3 successive biennial surveys with geocoded home locations allow a wealth of cross-sectional and panel data analysis. More analysis of change over time, not only in mode choice, but in other characteristics of travel behavior including awareness measures, would allow the Institute to understand its "customers." Combining this very complete data set with other aggregate data sets allows ever more detailed analysis. It can be used to verify local travel demand models, and to verify travel pattern predictions based on more aggregate data sets. This thesis has only begun to scratch the surface of what can be lovingly coaxed out of the data.

8.7 Hope For Implementation

The budgeting cycle for FY10 is complete, and MIT has approved a parking and transportation budget with room in it for a number of trial programs, provided they are cost-neutral in the short term. These trial programs include, but are not limited to:

- Limited Access Passes.
- A limited number of new students and employees on pay-per-ride passes, including those people who currently have Occasional Parking Permits.
- Integrating the CharlieChip into the MIT ID card, to be used by the above.

None of these programs will result in significant cost savings or behavioral change. However, they will establish the technical capacity to implement similar programs. They put MIT on the path to a wide-scale implementation of the proposals contained within this thesis. While it may be trite to quote Lao-Tzu that "a journey of a thousand miles begins with a single step," if you have been standing at the starting line without taking that step, any progress, however small, is infinite. In 2004, Hester concluded "ultimately the success of a [Universal Access Pass] program hinges on the acceptance of those who pay the bill. … Initial negotiations between parties, particularly during the pilot stage, might be long and slow." 5 years after she wrote those words there is hope that the first steps toward acceptance have been taken.

The myth of the single mode man is persistent. It can only be put to rest by policies that recognize that all parties have an interest in letting people be as multimodal as they naturally are. When people can take advantage of the choices cities provide, cities are more attractive places to live and work. If the long-run solution to a more sustainable planet requires reducing SOV demand, allowing cities to reach their potential is a necessary prerequisite.

9 EPILOGUE: UNIVERSAL ACCESS ON A CITYWIDE BASIS

Employers are not the only affinity group that can benefit from Universal Access Passes. Localities have a direct interest in reducing congestion and emissions. Commute Trip Reduction laws are implemented on a local scale. Reducing congestion improves the livability of the locality. Increasing the usage of public transit, and reducing the incidence of driving by the resident population, have additional benefits in gaining constituency support for complementary programs. These programs include street and sidewalk improvements, speed reduction, bike lanes, etc. It allows the locality to implement stricter Transportation Demand Management policies for employers.

9.1 ISSUES WITH EXISTING NEIGHBORHOOD ECOPASS PROGRAM AND SOLUTIONS

The traditional problem with extending Universal Access Passes beyond employers are two-fold.

(1) Coordination. Organizing neighbors into a coherent group that is equally responsible for payment requires either a strong neighborhood association, or a particularly dedicated core group of riders. Contracts require a responsible party to guarantee payment. The weak ties among these groups mean that yearly contracts must be paid upfront. This in turn removes the means for the transit agency to capture the increased transit usage, which is the goal of the program.

(2) Adverse Selection. Without a means of actual measurement, such as SmartCards, these programs, for example the Denver EcoPass, are based on area transit mode share. A flat price means that the groups that do organize tend to be those who use transit more than others. Even with SmartCards, the coordination problem is likely to prevent a change from fixed rate pricing to per trip pricing. Because of these program issues Denver's EcoPass has recently changed its pricing structure to discourage smaller neighborhoods from participating, and has halted new enrollment.

Instituting these programs with more formal actors can solve both these issues. Cities that take responsibility for the collection of Universal Access Pass program fees and transit agency payment have the power to coerce all—or a conditional subset of—residents to participate. Because of their larger budgets localities can be responsible for payment to the local transit agency on a pay-per-ride basis. This guarantees revenue neutrality for the transit agency for existing ridership and full payment for all new ridership. Thus neighborhood Universal Access Passes can be net positive for transit agencies.

9.2 CITY SPECIFIC ISSUES

Cities provide a number of implementation issues not found for employers. Their interest is similar in reducing drive trips, but it is not solely because of the use of limited parking facilities. Cambridge charges only a nominal rate for its current residential parking permits. This is meant not to discourage car ownership, but to discourage use of on-street spaces for non-residential purposes. Cambridge does not limit the number of parking permits they issue, so there is no means to know whether there is a supply constraint under current demand conditions. Reducing car ownership by residents is at best a secondary goal. Reducing car usage on the other hand, results in significant benefits for the city. However, pricing parking on a daily basis is not practicable, nor is it necessary desirable. We must ask ourselves; are the city's interests served if residents keep their cars in the same space every day, but do not use those cars for commuting purposes?

Those on-street spaces are currently significantly underpriced at $8 per year. Streets are public resources. Under current policy each side of most residential streets is not available to the public as a whole, but only to those people with residential permits for registered vehicles. With local parking prices at $100-$150 monthly for residential parking in the core areas of Cambridge (Craigslist), on-street parking is thus underpriced by $1,200 to $1,800 per year. By allowing unlimited, under-priced residential parking Cambridge thus removes a possible non-resident revenue source.

A Universal Access Pass program applied only to those people with current residential parking permits would increase the price of those spaces, in return for an additional benefit. Inasmuch as this reduces the number of people who park on-street, whether by encouraging a reduction in the number of vehicles, or encouraging people to make better use of existing driveways and garages, it would allow Cambridge to explore revenue possibilities for commercial on-street parking permits. Brookline, MA has implemented a commercial permit program that allows qualified local commercial businesses to purchase parking permits for adjoining residential streets for $500 annually. (Town of Brookline, 2009) Assuming that Cambridge is currently supply constrained, a reduction of 10% in the number of people parking on-street would free up almost 3,000 local spaces. Assuming that 1/3 of those are usable, there is the possibility of $500,000 in annual revenue from non-residents because of the spaces freed by a Universal Access Pass for residential parking permit holders.

9.3 Applying The Concept To Cambridge, MA

Because of the paucity of data on non-commute usage in Cambridge, any estimates of cost are necessarily gross, rather than detailed. The basic calculation is, as before, the transit usage of the affinity group dived by the number of people in that group. Transit mode share for the journey to work by Cambridge residents was 29.8% in 2007, up from 25% in 2000. Thus, under the assumptions that workers are representative of the Cambridge population, and that the only usage is by transit pass holders, each of whom uses the exact value of monthly pass, then a Universal Access Pass with mandatory participation by all residents would be priced at $211 annually, a 70.2% discount off the current monthly pass. Of course, none of these assumptions hold.

There are two conditions that likely need to be met for a successful program: (1) the program charge is avoidable by changing behavior; (2) the program targets the residents engaging in the behavior the City is attempting to influence. Therefore this thesis postulates that any program be required only for those people who have residential parking permits. If people use their cars for commuting, this will give them the incentive of zero marginal cost transit to stop doing so. If they do not use their cars for commuting and take public transit, they see a significant cost reduction. If they do not use their cars for commuting, and do not take public transit, they have an incentive either to use public transit, to move their cars into driveways, or give up the use of their cars entirely.

Based on 2005-2007 census estimates, there are 37,914 automobiles in Cambridge. Total ownership of vehicles by people who drive has been estimated based on the distribution of vehicle ownership by commute mode. Similarly, estimates of vehicle ownership by residents who take public transit, who use other commute modes including walking and biking, and households without workers, which are assumed to be students, have been created. To estimate costs requires a set of assumptions including (1) 20% of vehicles are stored off street across the board, except for people who commute by driving, who are more somewhat more likely to have off-street parking (this likelihood is mitigated by the fact that many residents get parking stickers in order to have the option to park on-street, because it is so inexpensive); (2) The total number of people in each group who hold a transit pass, and the usage of public transit by those people without a transit pass, based loosely on the distribution of passholders at MIT. This allows calculation of the average usage of public transit by each group, and therefore the total usage by residential parking permit holders. This totals $6.3m of usage annually, as shown in Table 9-1. This should be read not as a point estimate, but the midpoint of a range, which is likely to be +/-15-20%.

Table 9-1. Estimated Public Transit Usage By Cambridge Vehicle Owners

	Vehicles	% w/o permits	Permit holders	% w PT Pass	Usage by non-passholders	Average PT Usage
Non Worker HH	5,917	20%	4,734	10%	$6.80	$12.02
Drive	18,868	35%	12,264	0%	$3.40	$3.40
Public Transit	6,472	20%	5,178	100%	$-	$59.00
Walk, bike, other	6,657	20%	5,326	20%	$13.60	$22.68
Total	37,914		27,501			
Total Usage	$6,298,285					

Over a projected 27,501 participants, this amounts to a Universal Access Pass charge of $229 annually per person. With the expected margin of error and the current administrative fee, the total charge to residential parking permit holders for a program is thus approximately $20/month, a 67% discount from current LinkPass pricing. This does not take into account any change in behavior because of the pass, whether that is simply garaging a car off-street, or switching to commuting by public transit. Assuming that the distribution of usage by people without a transit pass is approximately normal, centered at the mean, with a standard deviation twice the mean 34% of all residential parking permit holders would see a cost reduction, and 60% would see a cost increase of less than $10 annually, a shown in Table 9-2.

Table 9-2. Distribution Of Universal Access Pass Costs For $20 Monthly Program

	% Saving Money	% Paying Additional Monthly $ above current transit usage			
		$5	**$10**	**$15**	**> $15**
Non Worker HH	18%	11%	14%	15%	42%
Drive	1%	5%	14%	26%	54%
Public Transit	100%	0%	0%	0%	0%
Walk, bike, other	42%	7%	7%	7%	36%
Total	34%	11%	15%	20%	19%

If approximately 10% of residential permit holders move their cars off-street, and thus eliminate their permits, than the price increases to $22 monthly, assuming those people are at the bottom end of the distribution of usage of public transit. Under the assumption of a transit demand elasticity for trips of -0.3 on the current number of permit holders who use transit to commute to work, this increases total costs of the program by $1.2m annually; the pass price increases to $27 per month, as seen in Table 9-3. This would amount to a 50% increase in usage by those permit holders who do not currently use public transit to commute to work. Assuming 50% of those trips are commute trips, this would increase citywide transit commute mode share from 29.8% to 32.7%.

Table 9-3. Annual Cambridge Universal Access Pass Cost

Annual Permit Fee	$240
Annual Permit w/ expected garaging	$264
Annual Permit w/ expected usage increase	$312
Annual Permit Fee w/ PT opt in	$360

The steep reduction in transit prices may be perceived as rewarding people who have a car, but do not use it, to the disadvantage of those people who have chosen a car-free lifestyle. Allowing non-permit holders to opt in, results in up to an additional 7,721 people participating, who use public transit for their daily commute (2005-2007 census estimates). Cambridge has incentive to maintain usage of local university transportation subsidy programs. A restriction to those people who have lived in Cambridge for 3+ years would reduce usage of the program by students. Moreover, given that this program is not pre-tax, the expectation that those people who have employer subsidies and pre-tax arrangements will not opt in to the program is defensible. By these assumptions only 50% of those people who currently take public transit opt in to the Cambridge Universal Access Pass program. Assuming these people use the full $59 of LinkPass value each month, this increases the per person monthly cost to $30. Including a conservative estimate of $500k in annual revenue form a commercial permit program, which Cambridge uses to reduce the cost of the program, would reduce the cost of each program by $2 monthly.

This has a relatively marginal effect on car ownership. For cars that are used less than 2,000 miles annually, ownership (not including depreciation) costs are more than $2,000 annually. For cars driven 10,000 miles annually, annual costs without depreciation are more than $4,000. (AAA Association Communication, 2008) Assume an optimistic -0.3 elasticity of demand with respect to non-depreciation ownership costs, and that 30% of the cars in Cambridge are driven rarely, and the rest are driven 10,000 miles annually. By these assumptions, this program would reduce car ownership by 514 vehicles, or 1.4%.

9.4 Implementation

Within a margin of error, a $25 Universal Access Pass program which is mandatory for parking permit holders, and optional for all other residents would be revenue neutral for the City of Cambridge, net positive for the MBTA, increase transit mode share by 2.9 mode share points, reduce congestion, emissions and vehicle ownership. Similar programs are widely applicable across the metropolitan area. Cambridge has one of the higher transit mode shares among local municipalities, and significantly higher usage of transit by non-commuters. For example, in Winchester, MA, public transit commute mode share is 9%. The majority of riders take Commuter Rail, which costs $135 monthly. There is likely little use of public transit for non-commute purposes. Therefore unlimited access to use the Commuter Rail station in the middle of town would cost $12 monthly. Arlington, MA is well served by numerous bus lines, but also likely sees little usage of public transit for non-commuting purposes. With a 19% transit commute mode share, they could give access to all MBTA subways and buses for less than $12 monthly.

Applying a program to the entire population, especially in areas without much use of on-street parking, would likely require a property tax levy. The current property tax rate in Winchester, for example, is just over 1.1% for residential real estate. This raises $56.5m. There are 22,604 people in Winchester. To cover every man, woman and child would require an additional $3.3m in revenue, or a 5.9% increase in property taxes. Cambridge raises $242m on a residential rate of 0.73% and a commercial rate of 1.72%. The complications of non-commute usage make the total value of resident's public transportation travel slightly harder to calculate, but it is likely somewhere in the range of $27m, assuming that the 71% of residents who do not commute via public transit use on average 1 round trip per week. This then would require an increase in property tax rates of 11.2% in order to support universal transit access for every man, woman and child in Cambridge.

The universality of a program based on property taxes is appealing, as are the equity considerations. Assuming that the property tax increase is fully reflected in increased rents, than people who are less well off pay less for public transit. Inasmuch as being poorer is correlated with a propensity to take public transit in the first place, this decreases costs most for those people who are least well off. Furthermore, it implies a subsidy that is mostly paid for by commercial enterprises rather than by residents – its effect is a required subsidy of transit. Even for those people who live in a house assessed at $1m, the increase in property taxes is $548. This is 23% lower than the cost of a single LinkPass on an annual basis, for a household that likely has at least 2 residents. The problem with a tax levy as opposed to an increase in residential parking permits is that it removes the incentive for people to remove their cars from a public commons. Moreover, it does not allow people the option of avoiding the fee. Incidentally, this would increase MIT's Payments in Lieu of Taxes by $2.8m annually. At those costs MIT could make public transit free for all of their employees.

There are administrative issues that would need to be overcome in order for a program to work, whether it is assessed on parking permits or via an additional levy on real estate. Cambridge would need to be responsible for any shortfall in revenue or increase in usage above what was expected. They would then need to change the annual rate based on the prior year's experience. In effect they would be a non-profit reseller of transit insurance, distributing the costs across the population, and taking the risks of the year-to-year variance. Cambridge would also need a mechanism that would automatically cap residents' usage at the LinkPass (or some other, risk-premium adjusted) rate.

This rough example demonstrates that a surcharge on top of residential parking permits, or an increase in property taxes, could significantly assist localities in meeting their professed goals to become more sustainable, livable, transit-oriented communities, with less congestion. A "free" transit pass becomes a competitive benefit of living in Cambridge. Inasmuch as this benefit is capitalized into home prices, it reduces the total cost of the program for residents.

9.5 Metropolitan Universal Access Passes

It seems *prima facie* unfair to require people to participate in both employer and city Universal Access Pass programs. Countering this requires establishing an order of primacy of the programs: does your employer program outweigh your city program? This thesis proposes that the employer program is primary. Employer programs allow pre-tax contributions to transit, thus allowing an implicit Federal subsidy of up to 40% counting both the employer and employee benefits. The person required to enroll in both programs would be refunded their imputed payment by the City. This would require an administrative mechanism to verify enrollment in an employer program.

Taken to its natural extension, if employers and cities compete to provide attractive benefits on Universal Access passes, each person has unlimited, zero marginal cost access to public transit. In effect, transit is fare-free for all residents of the metropolitan area, and the transit agency's collections come in lump sums from employers and localities, and individual payments by tourists, business travelers, and other non-residents. The transaction costs of the agency are significantly decreased. More significantly, the agency is insulated from the negative ridership effects of fare increases. The cost of transit is spread across the population – there is an incentive for people who do not ride the services to ride more. Rather than only transit riders having a direct interest in the health of the transit system, all metropolitan residents have "skin in the game." With passes in everyone's hands, this may assist the effort to stop excessive fare hikes. One could imagine Universal Access Passes being extended statewide. For example, a small surcharge to driver's licenses could pay for all of the MBTA usage by Western Massachusetts residents. An increase in the per-trip fare, without commensurate increases in the Universal Access cap, allows agencies to increase their revenues from tourists without negatively affecting their residents. Of course, a Universal Access Pass could work for hotels as well, as an increase to room rates based on expected usage by guests, integrated with their room keys.

Universal Access Passes are relatively inexpensive benefits, whose charges can be passed along in a multitude of ways. Inasmuch as the charges are applied to behavior to be discouraged—whether because that behavior is highly subsidized and thus expensive, or because it has negative externalities, or both—the benefits are compounded. They provide incentives for people to use more sustainable modes of transportation, and give people more flexibility in their daily mode choice. With wide scale adoption Universal Access Passes could lead to fare-free transit and commensurate increases in transit funding. Through collective participation Universal Access Passes allow people to incrementally break the constraints of the single mode man.

APPENDICES

APPENDIX 1. SURVEY RESPONSE BIAS: WEIGHTING

This thesis works with a known population at MIT. Rather than applying standard statistical techniques, corrections for both invitation and response bias are achievable by comparing the respondents to the population in a more accurate manner. After data exploration significant biases were manifested in two known population characteristics: Job / Student Type, and type of parking pass or permit purchased.

As shown in Table A-1, Service Staff were not invited to the survey (neither union employees nor people without e-mail addresses were invited). Also not included are 1,000 freshmen undergraduates on-campus, who were not invited to take part in the survey. Response rates overall are quite variable between groups. Inasmuch as position is a proxy for travel behavior, failing to re-weight the sample to compensate for this known deviation from the population will bias results.

Table A-1. Response Rates Student / Employee Type, 2008

	Invited but did not respond	Invited and responded	Not invited	Total
Student: Undergraduate: On-Campus	34%	64%	2%	1,689
Student: Undergraduate: Off-Campus	34%	66%	0%	904
Student: Graduate: On-Campus	31%	54%	15%	2,129
Student: Graduate: Off-Campus	43%	57%	0%	3,561
Faculty	46%	46%	7%	1,008
Staff: Other Academic	30%	30%	40%	3,913
Staff: Admin	20%	75%	5%	2,091
Staff: Support	23%	64%	13%	1,689
Staff: Service	0%	0%	100%	854
Staff: Sponsored Research	15%	28%	57%	3,723
Staff: Medical	32%	49%	19%	112
Total	28%	47%	25%	21,673

As shown in Table A-2, people who do not receive benefits from MIT or who receive only parking benefits have a lower response rate. Thus, without re-weighting the sample to the population, results will be biased in favor of transit behavior.

Table A-2. Response Rates By Benefits, All Employees And Students, 2008

	Invited but did not respond	Invited and responded	Not invited	Total
None	28%	36%	35%	11,420
Bus Pass	26%	61%	12%	209
Link Pass	29%	61%	10%	4,097
Commuter Rail	20%	69%	11%	467
Occasional + Bus Pass	21%	70%	9%	33
Occasional + Link Pass	20%	73%	7%	589
Occasional + Commuter Rail	14%	84%	3%	291
Occasional Permit	23%	46%	31%	806
Resident Permit	39%	56%	5%	484
Carpool Permit	23%	56%	21%	248
Commuter Permit	32%	54%	14%	3,029
Total	28%	47%	25%	21,673

Based on the ratio of the total number of people in the population to the survey respondents in these dimensions three different types of weights were created: (1) Weighting all survey respondents to the entire population (shown in Table A-3); (2) Weighting all respondents who are eligible for transit benefits (student, or paid to work at least half time and on the main MIT campus) to the eligible population (3) Weighting just eligible employee respondents to the eligible employee population. Each of these populations also requires the creation of a proportional weighting system scaled to the respondents rather than the population. This allows correction for known issues with population weights, namely that they inflate the expected significance of any measure where the sample size is in the denominator. Thus, with measures such as standard deviations and confidence intervals this thesis uses weighting to the total number of respondents rather than the population, with no loss of accuracy.

There were two cases that required further inference. Service staff and freshmen were not included on the invitee list. Freshmen were assumed to have the same behavioral patterns as other on-campus undergraduates. Service Staff were assumed to have the same patterns as the rest of the respondent group.

Table A-3. Sample Weighting – All Students And Employees To Population Proportion

	Student: Undergraduate: On-Campus	Student: Undergraduate: Off-Campus	Student: Graduate: On-Campus	Student: Graduate: Off-Campus	Faculty	Staff: Other Academic	Staff: Admin	Staff: Support	Staff: Service	Staff: Sponsored Research	Staff: Medical
None	1.14	0.69	0.83	0.91	1.20	2.28	0.87	1.20	-	6.24	1.10
Bus Pass	0.96	0.63	0.75	0.70	0.45	0.62	0.66	0.68	-	1.43	-
Link Pass	1.04	0.69	0.84	0.69	0.69	0.79	0.57	0.63	-	0.89	0.75
Commuter Rail	0.90	0.45	1.66	0.71	0.72	0.83	0.54	0.53	-	0.70	0.45
Occasional + Bus Pass	-	-	-	0.45	-	0.68	0.53	1.05	-	0.54	-
Occasional + Link Pass	-	-	3.62	0.69	0.62	0.61	0.52	0.61	-	0.57	0.90
Occasional + Commuter Rail	-	-	0.45	0.60	0.69	0.48	0.50	0.49	-	0.58	0.63
Occasional Permit	-	0.45	-	0.72	0.95	1.09	0.57	0.59	-	0.75	1.66
Resident Permit	1.08	0.60	0.82	0.87	0.87	0.66	0.60	-	-	-	-
Carpool Permit	0.72	0.45	0.45	0.72	0.65	1.05	0.62	0.63	-	0.69	0.45
Commuter Permit	-	1.36	3.16	0.66	1.10	1.04	0.62	0.68	-	0.75	0.94

As shown in Table A-4, Weighting the sample results in significant corrections for response bias. For example, both people who drive and people who take public transit disproportionately respond to the survey. Using the weighting methodology, in this case for the entire population, results in more accurate description of actual behavior on campus.

Table A-4. Weighted Vs. Un-Weighted Monday Mode Share, All Students And Employees, 2008

	Un-weighted	Weighted
Drive Alone	15.25%	12.38%
Public Transit	29.47%	25.94%
Carpool	7.09%	6.36%
Pedestrian	37.88%	44.67%
Not on Campus	7.50%	7.59%
Other	2.81%	3.07%

This thesis operates under the assumption that the non-respondents to particular question, as long as they amount to less than 5%, are similar to the respondents. Thus individual measures require a simple re-weight of the scaled responses to population proportionally. Subsets where there is greater variance in response—such as responses to the number of boardings by bus and subway route—use a separate scale by which to weight responses, based on the same methodology above, but using only the respondents to the question at hand. This use of different weighting measures means that for different questions throughout this thesis there are slightly higher or lower row and column totals than exist in the population. The margin of error created by this variability is less than 1%.

Weighting on multiple characteristics when using panel data is more difficult. There is neither a definitive population, nor is it evident that benefit type or employee / student type holds between years. When making comparisons between years, this thesis endeavors to use actual totals wherever practicable.

Appendix 2: Experimental Design Of Transit Benefits Eligibility On Pass Purchases

Those people at MIT who are ineligible for benefits are mostly "Other Academics," hereafter known as non-Faculty Academics, who have a more transit friendly predilection than other employee groups. To control for this bias requires comparing these non-benefits eligible employees to non-faculty Academics who are eligible for benefits. There is also need to control for why they are not eligible for those benefits. For the most part, they are ineligible because they are not paid by MIT, but are funded by other Institutions. The implication for transportation is that they may not be commuting to MIT on a regular basis; the questions they answer about their commute may be referring to a commute to a different location. In fact, 36% of non-Faculty Academics work fewer than 17 hours per week on campus, and an additional 17% work fewer than 30 hours. Removing these observations from the sample leaves regular commuters to the main campus of MIT. A proper comparison requires removing the non-faculty academics who are eligible for benefits, but work fewer than 30 hours per week, a total of 14% of this group. This leaves 613 non-Faculty Academics who receive benefits, and 218 who do not.

The data shows that the experimental and control groups are similar in gender, age distribution, arrival times, parking location, most recent move date, and distance to MIT, with one notable exception:

- Gender composition is similar, with 31% of the control (no transit subsidy) sample female, and 31% of the experimental (subsidy) sample female.
- The experimental group is slightly younger:[19] 16% are below 28, 23% are 29 or 30, 34% are 30-35, 12% are 36-45, and 15% are over 45, whereas in the control group, 14% are below 28, 9% are 29 or 30, 31% are 30-35, 27% are 36-45, and 18% are over 45.[20] That is, the control group has exchanged approximately 15% of the sample from 36-45 year olds to 29 or 30 year olds.
    - This difference has a relatively large effect on drive mode choice (5% of the 29-30 year olds drive every day, vs. 21% of the 36-45 year olds, with an additional 6% in both groups driving sometimes), and a commensurate effect in the opposite direction for pedestrian behavior (34% of the younger group are every day pedestrians vs. 16% of the older group, with an additional 12% occasional pedestrians in the former, and 10% in the later.) However, it has a lesser effect on transit usage, at 37% vs. 34% using transit every day, with an additional 17% using it occasionally for the younger cohort, and 18% for the older cohort. The expectation is that the control group—with 15% more of the older cohort—will have approximately 0.5% less every day

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[19] Slightly younger may be correlated with less seniority and a combination of less access to parking, and possibly less suburban home origins.

[20] These rather strange age brackets are used because they best fit the data. Non-Faculty Academics include a large contingent of post-Doctoral researchers. Many of these people are at MIT on grants that are not tied to research contracts at MIT, and thus are not eligible for benefits. Commonly they have taken 5-6 years after finishing their Bachelor's degree, and thus are 28 and 29.

transit, 3% fewer pedestrians, and 2.5% more every day drivers, as well as about 1% more people ridesharing.

- The control and experimental groups have approximately the same distribution of arrival times at MIT.
- They both tend to park in the same places on campus when they come via car. That is because MIT does sell Parking Permits to non-eligible employees for a slightly higher rate.
- They have the same distribution of the last time they moved, and placed statistically the same importance on proximity to MIT and public transportation in their location choice.
- The control group currently lives slightly closer to MIT (35% within 1 mile vs. 31% for the experimental group), and the opposite for the second mile (15% vs. 19%), but afterward the distribution of their distance to MIT is statistically the same. There is a 22% decrease in the share of people or walk or bike every day for the increase from a commute under one mile to a commute of 1 to 2 miles. This leads to an expected 0.9% increase in pedestrian behavior in the experimental group. There is also a 17% increase in transit usage for that extra mile in commute distance, which, which would amount to a 0.7% increase in transit mode share. These are not fully additive with the expected difference based on the age distribution, since age and location are highly correlated.

The preceding allows an examination of the differences in exogenous factors above and beyond the expected difference due to their different profiles.

APPENDIX 3: PHOENIX VALLEY METRO'S PLATINUM PASS: DECADES OF PAY-PER-RIDE EXPERIENCE

BASELINE SITUATION

Phoenix is located in Maricopa County, Arizona. Maricopa County has approximately 3.7m people in 9,226 square miles. The major transit operator in the area is Valley Metro transit. As of 2008, 46% of the county's population was within 1/4 mile of the 266 route miles of bus service. Valley Metro is the successor to the Regional Public Transportation Authority (RPTA), created in 1985. RPTA began with a small portion of the funding from a voter approved proposition of a one-half cent sales tax to increase freeway construction. Over the last 20 years, cities in the service region, including Tempe, Mesa, Glendale, and Phoenix, have passed sales tax increases with portions dedicated to transit improvements. RPTA changed its name to Valley Metro in 1993. What began with bus service operated by private contractors, with no Sunday service, will soon also include a light rail system. As of 2008, Valley Metro provides 64 local, and 21 express/rapid routes, with 939 vehicles in operation for 33 revenue miles of service. Peak headways are 10 minutes on light rail, and 15-30 minutes for most bus service. Fare revenue is $41m, on operating expenses of $184m for bus services. Annual ridership is just over 60m trips annually. (Valley Metro, 2008)

In 1985, Maricopa County was sued for failure to meet the National Air Quality Standards. To meet the court ordered implementation of a State Implementation Plan (SIP), the Arizona Legislature passed an air quality bill in 1988, part of which mandated a Trip Reduction Program (TRP) for all employers with 100 or more employees. In the last twenty years the law has been amended to apply to all employers with 50 or more employees. Employers must attain a reduction of trips or miles travelled to their worksite by employees of 10% per year for the first 5 years, and 5% per year thereafter, or maintain an SOV mode share of 60% or below. Non-attainment after three years leads to a mandate to implement at least 4 of the following measures: paid (as opposed to free) parking, preferential parking for carpools, telecommuting, compressed workweek, subsidized vanpool, subsidized transit, guaranteed ride home, day care facilities, showers and locker facilities, "prize drawings" for using non-SOV modes, and "recruit(ing) and reward(ing)" non-SOV converts and people who move closer to the worksite. The task force that administers the program encourages transit subsidies where there is service available. Employers can also implement Equivalent Emissions Reduction (EER) programs. In these programs, employers claim credit against the TRP through employee ownership of cars that meet CA LEV standards, programs that move traffic from the peak, and programs that remove older, high emitting vehicles form the road. (Maricopa County Board of Supervisors, 1997)

HISTORY & GOALS

In response to the mandated TRP, in 1991 Valley Metro (at that time, RPTA) began the Bus Card Plus program. Its goal was to allow employers to implement required elements of their TRP, and to increase ridership. Secondarily, Valley Metro wanted to increase cashless transactions and increase measurement accuracy, as well as reduce misuse. The program began with one major employer - Valley National Bank, acquired by Banc One in 1993, which changed its name to Bank One in 1998, and was acquired by J.P. Morgan Chase in 2004. The Bus Card Plus program is a Pay-per-ride system, where employers distribute fare media to their employees, and pay Valley Metro the full fare value for each ride their employees take, up to a cap of the monthly pass price. Employers are allowed to charge their employees any amount for the cards they wish, either on a pay-per-ride or monthly basis, up to the retail value. Because this program is usually part of a TRP plan, most employers subsidize the cost, although there is no available data on the extent to which this is the case. As of January 2009, the program is now called the Platinum Pass. (Reid, 2008)

The program was not widely expected to be a successful component of TRP programs. Bus service in 1991 was oriented to captive rather than choice ridership. In 1993, 37% of the population riding Valley Metro was minority, as compared to 24% in the area served. 66% of ridership was classified as captive, because of lack of availability of other means of transport. (Schwenk, 1996) Any ridership coming from TRP plans is by definition choice ridership, since it comes from employees who formerly were SOV commuters.

Implementation

When the program began, as Bus Card Plus, electronic fare media were distributed to employers, who then distributed the cards to their employees. In early 2009, this fare media was replaced by Valley Metro's new SmartCards. The distribution process has remained the same. Valley Metro issues cards to employers that include the company name and the employee's ID number. Cards are activated on first use, and remain active for 3 years after they are issued, unless cancelled by the employer. There is a check against a hotlist of invalid cards at the farebox. Employers receive a single monthly bill for all of the uses by their employees. They can opt to receive a detailed billing summary of the date, time and route for each boarding for a nominal fee. (Schwenk, 1996) The monthly cap is variable—$45 for local routes, and $68 for trips on Express/Rapid routes. As of 2003 there were 4 full time employees working on the program, and total administrative costs were approximately $360,000 annually. (TCRP Report 107, 2005)

Participation & Results

As of 2003, there were 331 employers participating in the (then) Bus Card Plus program (TCRP Report 107, 2005), up from 182 in July 1995 (Schwenk, 1996). 12,189 employees were participating, for an average of 35 employees receiving a pass per employer. This represented 11% of total system ridership (TCRP Report 107, 2005), up from 193,000 monthly uses representing 7% of system ridership in 1996 (Schwenk, 1996), and $3.6m in revenues. At full fares these passes would have brought in $313,350 per month at the monthly cap value. With the Pay-per-ride program and the monthly cap they actually brought in $251,695. (TCRP Report 107, 2005)

The goal of examining these revenue numbers in depth is to get a sense for how hard it is to determine revenue, even when relatively good fare collection data is available. The above numbers do not give an indication of how many employees were subject to the cap. For example, it could be that no one hits the cap, but that employees on average only used 80% of the fare value of the pass. Monthly passes are priced at 27-29 rides per month (regular vs. express fares). If no one hits the cap, Bus Pass Plus revenue implies that the average usage was 22-23 rides per month. On the other hand, if 50% of riders were at the cap, and the other 50% were underneath, this would imply that the employees beneath the cap used it for 61% of the value of a monthly pass on average, or 16-17 rides per month. If all of the participants in the first case were prior pass purchasers, Valley Metro's program is leads to 20% loss in revenue. If all of the participants in the second case were previous pass purchasers, the revenue loss is 10%. However, if the program attracted net new riders, it could well be revenue positive. A monthly-capped program creates revenue loss, if it does not increase ridership beyond what it would otherwise be. If these programs are rolled out with new employers, they permit additional employees to pay for transit within the federal tax subsidy. This then represents additional value for the transit agency in attracting net new riders.

Valley Metro has not tracked participation over time, and does not track who subsidizes the program. Anecdotally, Valley Metro has indicated that employers subsidize transit for 3 to 6 months, and then stop their subsidy. (TCRP Report 107, 2005) While this thesis was not able to obtain recent data on transportation subsidy participation, the average subsidy per employer ranged from $5.39 to $14.26 depending on the size of the employer. (Maricopa County, 2005) At a monthly pass cost of $45, this could mean that subsidies range from 12% to 32% for all employees, or that subsidies are 100%, but only 12-32% of employees participate, or, more likely, somewhere in between. There is some indicator that these subsidies are successful in changing mode - the 2005 TDM survey reports that 49% use alternate modes in TRP organizations, vs. 39% in non-TRP organizations, although this may be a result of a difference between smaller and larger companies, and includes modes other than transit. (Maricopa County, 2005)

Supporting the proposition that Valley Metro saw revenue loss from the program, for those employers that do subsidize the cost of their employees' transit, the Bus Card Plus resulted in large reductions in cost. For example, the City of Phoenix reduced their subsidy cost from $30,000 to $19,000.

Valley Metro program adminstrators report that they are satisfied with the program, and believe that employers are as well. They are of the opinion that the program has increased ridership and revenue, but do not have any data to support this assertion. (TCRP Report 107, 2005)

Appendix 4: Denver's EcoPass: Does Universal Access Increase Revenues?

Baseline Situation

The Regional Transit District (RTD) runs the Denver metropolitan area's bus and light rail service. The Colorado General Assembly created RTD in 1969 to replace the Denver Tramway Company, a private operator of streetcar service until the 1950's, and bus service thereafter. RTD began planning immediately, but did not take control of services until 1974. RTD ran bus service only until 1994, when Denver's first light rail line was built. As of 2008, The RTD service area contains 2.6m people in 40 municipalities and 6 counties spanning 2,331 square miles. There are 51m service miles annually, running over 10,329 bus stops, and 170 routes, including local, express, regional and SkyRide (airport) services. RTD owns 1,060 buses, 862 of which are in service at peak hour. This is supplemented by 91 light rail vehicles running over 35 miles of light rail tracks with 37 stops. There are 93m annual boardings; 17m of which are on the light rail system, 61m on the various bus routes, and the remaining on dial-a-ride services and a free shuttle in the 16th Street pedestrian mall. The system has a $458m annual operating budget.

Before the January 1, 2009 fare increase, fares were $1.75 per trip on local service, $3 per trip on express routes, $4 for regional service, and prices from $7 to $11 for SkyRide service. Passes ranged from $60 monthly for local service, to $108 for express, and $144 for regional, or 34-36 trips per month. Now fares are $2 for local service, $3.50 for express service, and $4.50 for regional routes, with an additional dollar added to SkyRide fares. Monthly passes are now $70, $128 and $164, or 35-36 trips per month. Light Rail is a zonal service, at the same pricing as local, express and regional service. Annual passes are available for a one-month equivalent discount. (RTD Denver, 2008)

History & Goals

Unlike Phoenix, Denver RTD did not have the built in incentives of a state mandated Commute Trip reduction ordinance to encourage the development of an innovative TDM program. Instead, Denver's Universal Access pass program for employers (EcoPass) emerged at a similar time as their University program (CollegePass), out of local initiatives in the Boulder area, and was later adopted on region-wide scale. The CollegePass program grew out of a parking problem at the University of Colorado at Boulder. UC Boulder had limited parking available for its students, and thus had an incentive to look for a program to reduce SOV travel to campus. There was a student referendum in support of the program, and funding provided by the City of Boulder to Denver RTD to cover administrative costs. EcoPass emerged from an agency called Go Boulder, part of the City of Boulder, which was a local provider of TDM solution. They started a pilot program in 1991 with 6 employers and 300 employees. Thereafter, Denver RTD began offering the program on a region wide basis. (Hester, 2004)

Denver's EcoPass program is open to all employers in the Denver RTD service area. Denver RTD has split their service area into four service level areas (SLAs), based on the amount of service available in the area and typical mode shares. (Pung, 2008) Pricing is based on both service area and number of employees. Higher pricing for smaller companies allows Denver RTD to control for adverse selection, wherein smaller participating companies can result in revenue loss. This is explored in more depth later in this section. Prices ranges from $45 annually per employee for companies over 2,000 employees in outer suburban SLA A, to $400 annually per employee for companies under 24 employees in SLA D, covering the Central Business District. Employers are required to pay for all permanent employees on their payroll, not the number who use transit service. It is a Universal Access pass, plus a Guaranteed Ride Home program. Employers can choose whether—and to what degree—to subsidize the cost of the program, and whom to charge—all employees, or just regular transit riders. Both the employer subsidy and the employee contribution qualify for Federal Transit benefits, and thus are pre-tax. (Pung, 2008)

The goal for the program is to increase ridership while maintaining pre-program revenue yields. Specifically, the pricing criteria as adopted by the RTD Board in 1991 were 1) Cost neutrality (as measured by estimated average farebox revenue per employee before and after EcoPass); 2) Recover "a portion" (amount unspecified) of farebox revenue from ridership growth due to EcoPass; 3 & 4) Create a funding reserve for new service (both capital and operating) required by expected ridership growth due to the program; 5) Recover administrative costs; 6) Recover cost of guaranteed ride home. (Denver RTD, 2008) Criteria 1 and 2 specifically contradict the remaining criteria. If the program is cost neutral on a per employee basis for existing employees, but only recovers a portion of revenue from new ridership, than any service added for new ridership would see a lower marginal farebox recovery than the system-wide average farebox recovery. It would be unlikely that a sufficient amount of reserve would be accumulated to meet the increased need. On the other hand, if the program attracts net new riders but does not require marginal increases in service, than all the goals can be met, including administrative cost recovery.

Annual per employee charges and service areas have changed over the years. In 1991 there were four service areas, with annual cost ranging from $20 to $245 per year. In 1993, the first two Service Areas were combined, and 3 pricing levels added by company size. In 1996, Denver RTD added a monthly minimum contract of $200. They increased pricing by 18% in 1997 and added a new category for employers over 1,000 employees. In 2000 they increased the minimum contract to 5 employees, and added a pricing level for companies over 2,000 employees. In 2002, there was a 6% price increase, and a new minimum contract structure based on both employer size (1-10, 11-20 and 21+ employees) and SLA. This minimum contract was based on equivalent fare type in the area, so for example, in SLA A (suburban), employers with less than 10 employees had a minimum contract equivalent to the cost of 1 local pass, employers with 11-20 employees had a minimum equivalent of 2 local passes, and employers with 21+ employees has minimums equal to 3 employees. In 2003, cash fares, minimums, and EcoPass pricing were all increased by 6%. In 2004 the increase was 13%, in 2006 10%, and in 2008 12%. During this time the service area map changed year by year as well. (Denver RTD, 2008) In other words, by creating a program with defined boundaries and employer sizes, Denver RTD has been required to make periodic adjustments in order to meet the revenue goals of the program as outlined by the RTD board.

Denver RTD also runs a Neighborhood Pass program, with a similar structure to the employer program. All housing units in the neighborhood receive a pass, in return for annual fee paid by a neighborhood organization, city, or county with defined boundaries. Much like employers, neighborhoods can define who pays, and how much, whether as a separate voluntary contribution, or as part of a homeowners or other dues collecting group. This requires a strong core of residents to organize the program on behalf of their neighbors. It is difficult to mobilize such large groups, with little mechanism by which to collect money from the affinity group, except voluntarily. Those groups that do organize are therefore likely to have a higher percentage of transit riders. Adverse selection is defined as the propensity for program particpation by those groups who use the program more than projected. With pricing determined based on area mode share, when adverse selection is prevalent, and the total cost of the program is designed to be revenue neutral for existing riders only (without an additional reserve for expected net new riders), than the program as a whole results in a revenue loss against the baseline fares collected. This seems to have been in the case with the Neighborhood Pass in Denver. In 2008, Denver RTD initially proposed to increase the minimum contract for the neighborhood pass. Ultimately, it decided to suspend any new enrollments in this program as of January 2009, until it has rolled out SmartCards, allowing usage to be tracked. (Leib, 2008)

IMPLEMENTATION

EcoPasses are imprinted with an employee's photo. Cards are created at one of three sites throughout the Denver metropolitan area, or photos can be submitted digitally and the cards sent to the employer. For employers with more than 50 employees, Denver RTD will arrange onsite photos for no additional charge. To board buses, employees show their passes to the driver. On the light rail EcoPass holders show their pass to the fare inspectors if and when they are asked. Rides are tracked by manual keypress by bus drivers, and fare inspectors. There are also quarterly manual counts conducted. Denver RTD has been evaluating Automatic Fare Collection (AFC) system for the last 5-7 years, and is set to begin implementation this year.

When new employees are hired or fired during the year, charges to the employer are pro-rated. To receive new cards, or credit for headcount reductions, employers must inform Denver RTD of any change in status of their employees throughout the year. Contracts are for one year, and are renewable from October through December. Employers must return all existing cards to Denver RTD at the end of each year. (Sabrsula, Castro, Widdel, & Plooster, October 2008) Administrative costs ranged from 1-7% of sales from 1992 to 2002. (Nuworsoo, 2004) Denver RTD also provides promotional assistance, including transit fairs, to employers.

Participation & Results

As of October 2007, 1,578 companies with 88,382 employees participated in the EcoPass program. As shown in Table A-5, Employees are distributed among the service areas, but the majority of the companies are on the urban fringe, and the majority of the revenue comes from the CBD.

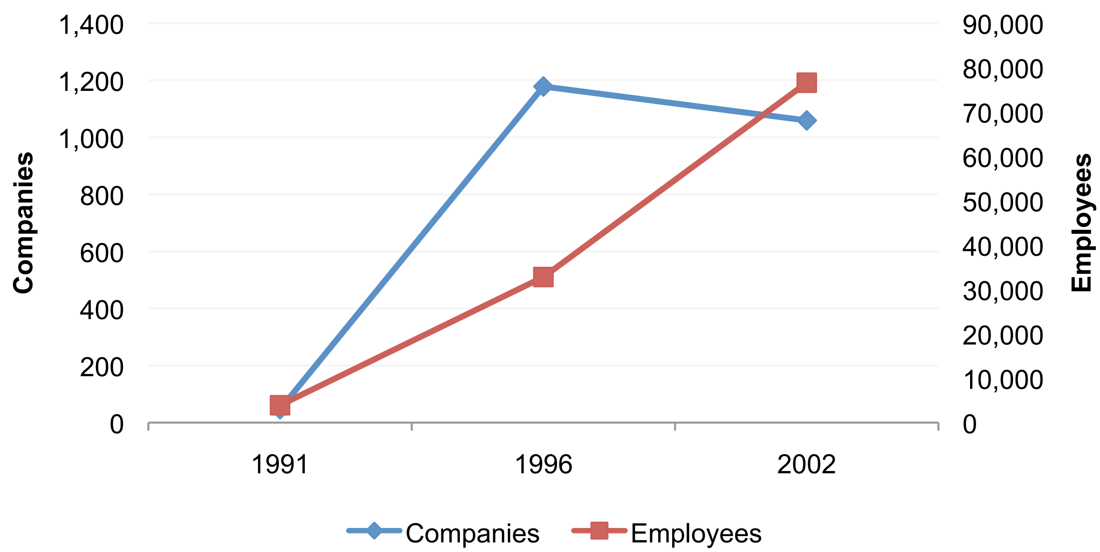
As shown in the Figure titled "Growth of EcoPass Participation" the average size of employer increased from over 80 employees at inception, to less than 30 in 1996, to more than 70 in 2002, and stands at 56 as of October 2007. (Denver RTD, 2008) The major growth has been in small employers throughout the program, except for 1996 to 2002, where most of the growth was in large employers. As of 1997, EcoPass was held by approximately 13% of all downtown employees. (Nuworsoo, 2004) The table entitled "Denver RTD Distribution of EcoPass Participation and Revenue" shows that while most of the employers are in the inner ring suburbs (SLA B), most of the program revenue comes from the CBD (SLA C).

Table A-5. Denver RTD Distribution Of EcoPass Participation And Revenue

	Companies	Employees	Revenue
Denver CBD (SLA C)	23%	31%	62%
Major Transit Centers (SLA B)	62%*	29%	19%
Outer Suburban Areas (SLA A)	13%	36%	11%

* 90% have fewer than 25 employees
Source: (Denver RTD, 2008)

Figure A-1. Growth Of Ecopass Participation



Source: (Denver RTD, 2008)

Because Denver RTD's fares vary depending on the services used, it is hard to estimate the exact ridership these prices imply. SLA A is based on local service, and the others are based on a mix of all services, based on ridership in the EcoPass program, which is approximately 1/3 local, 1/3 light rail, and the remainder split more or less evenly between express, regional and SkyRide. For service level A that means a comparison to the annual pass price for local service, which was $660 before the fare increase. For the other SLAs it requires calculating a weighted average of pass types based on EcoPass ridership, which is $1,120, pre January 2009 fare increase. By simple arithmetic the imputed mode share for SLA A is 5-9%, for SLA B is 9-12%, and for Service Level C is 26-31%.

The minimum contract price for these areas is designed to reduce variability that causes adverse selection issues, where the only participating employers are those on whom Denver RTD loses revenue. For example, imagine 50 companies in Service Level A, each with 5 employees. The expected mode share in SLA A is 7 to 11%. Because of the small company size, a high variance in transit usage between companies is expected. Most will have 0% mode share, but some will have 50% mode share. In this case, you would see adverse selection, where those companies with high mode shares participate and those without do not. The result would be loss of revenue for Denver RTD, as only those companies with 50% mode share would participate, but without a minimum contract, Denver RTD would charge the equivalent of 7-11% of the cost of a pass per employee. In other words, Denver would lose up to 39% of the revenue that it formerly received. Minimum contracts increase the expected number of employees per company, guarding somewhat against the variance that creates adverse selection. As part of its most recent fare increase, Denver RTD proposed to increase the minimum contract to the equivalent of 3-6 annual full-fare passes per 10 employees for companies with fewer than 30 employees.[21] This was roundly criticized. (Leib, 2008) Denver RTD ended up changing the minimum structure to 1-3 annual pass equivalent per 10 employees for companies fewer than 30 people, depending on service area.

In 2007, the SkyRide airport service was approximately 24% of farebox equivalent revenue (the percentage of total revenue on a per trips basis) from EcoPass, as opposed to 9% for the system. Because SkyRide has a high premium on fares compared to the rest of the system, and had no additional cost for the employer, it may have led to a decrease in revenue. As of January 2009, employees are required to pay a $5 surcharge for each use of SkyRide. (Denver RTD, 2008) Essentially, this removes a $5 subsidy for each use. If this is removed, based on numbers provided from 2007, SkyRide represents 9% of farebox equivalent revenue. This proportion is in line with the system average; some semblance of revenue neutrality from this portion of the program is restored. However, with airport trips now employee paid, program value is reduced, especially for employers who do a lot of business out-of-town. This may decrease employer participation in the future. There are tradeoffs in program design.

[21] The numbers vary depending on Service Level area.

EcoPass represented 11.4% of system wide boardings in 2007, up from 7.8% in 1997, and 16.6% of revenue, up from 9.8%. (Denver RTD, 2008) Because of the variation in fares between areas, this does not necessarily mean that the program was revenue neutral in 2007, but lost money in 1997, or the reverse. Revenue neutrality in its most expansive definition, where net new riders are included, can be estimated via the ratio of imputed farebox revenue (what would have been collected had all rides been sold on a per-ride rather than pass basis) to actual revenue for both the system as a whole, and for the EcoPass.[22] To the extent that this includes new ridership, this measure implies a high degree of farebox recovery from those new trips.

This thesis uses an estimate of the distribution of fares by fare type for both EcoPass and the system as a whole from 2007, combined with cash fares for each fare type, to estimate the imputed revenue from both EcoPass and the entire system in 2007, presented in the table below entitled "Denver RTD EcoPass & System Wide Actual vs. Imputed Revenue, 2007". The cash fare for light rail varies by zone, requiring the assumption that zones are used in the same ratio for light rail as they are for bus service, so that the average fare—pre-fare increase—is $2.45. Based on these assumptions, the ratio of imputed revenue to actual revenue is approximately 2.32 for the EcoPass vs. 2.33 for the system. In other words, by this rough estimate, Denver RTD receives the full fare from EcoPass for both existing riders and net new riders. If cash fares represent 20% of all fares system wide, and senior and discounted passes are more or less revenue neutral otherwise, than the system ratio increases to 2.67, which would imply that EcoPass is revenue positive.

Table A-6. Denver RTD. EcoPass & System Wide Actual Vs. Imputed Revenue, 2007

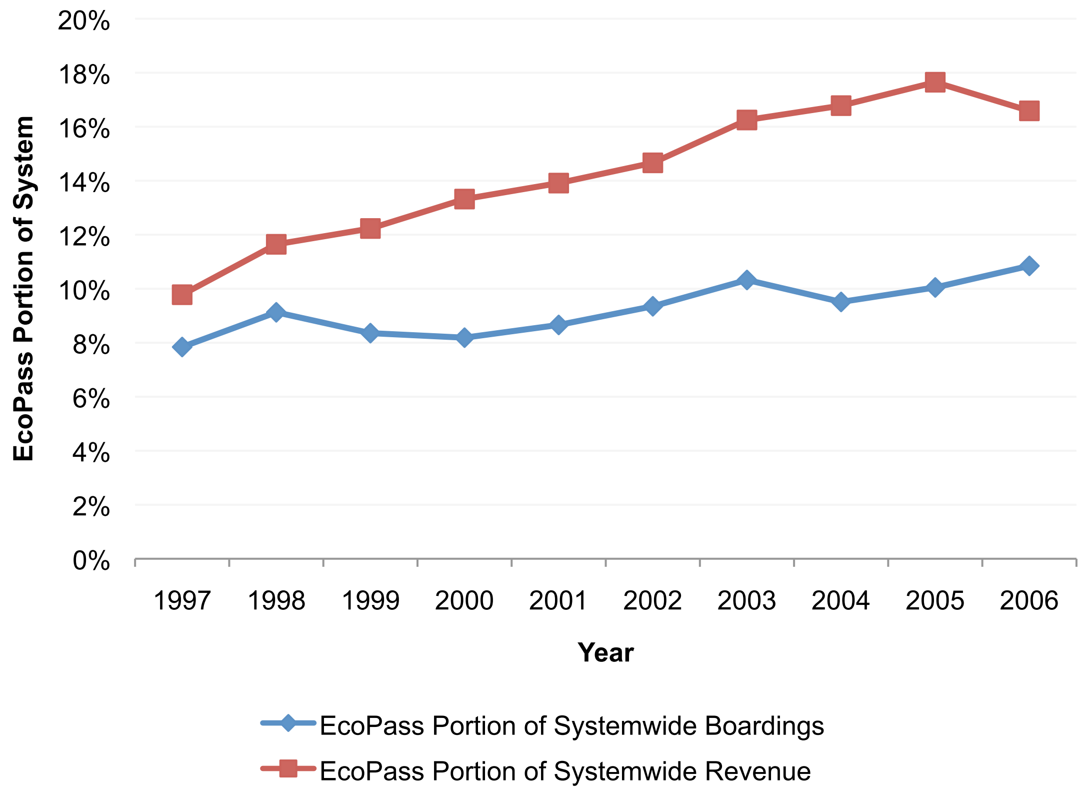
	Boardings		Imputed Revenue	
	EcoPass	**System wide**	**EcoPass**	**System wide**
Local	3,171,636	53,487,212	$5,550,363	$93,602,621
Express	801,486	2,179,678	$2,404,458	$6,539,034
Regional	1,144,966	3,479,150	$4,579,864	$13,916,600
SkyRide	870,624	2,049,168	$6,094,368	$14,344,176
Light Rail	3,325,965	18,685,196	$8,145,605	$45,761,825
Total	9,314,677	79,880,404	$26,774,658	$174,164,256
		Actual Revenue	$11,546,394	$74,662,666*
Ratio of Imputed to Actual Revenue			2.32	2.33

* scaled from 2006 by boardings

[22] Ideally, this calculation would remove University Passes, Neighborhood Passes, Seniors and other discount fares from the system calculation, but the proper data is not available. Increasing accuracy would take into account cash sales, and deflate the system wide imputed and actual revenue by the same amount, since they are equal for these fares. Because these corrections are lacking, this measure may be biased in either direction.

As can be seen in the figure below, "Denver RTD EcoPass vs Systemwide Revenue and boardings," the ratio of EcoPass revenue per boarding to system wide revenue per boarding has varied significantly over the 10-year period for which data is available. This variation is likely due a changing distribution of where employers are located, and thus their usage of services with different fares. Because of this changing distribution this ratio is not a good measure of success on its own.

Figure A-2. Denver RTD EcoPass Vs System Wide Revenue And Boardings



Source: (Denver RTD, 2008)

Ridership and Mode Share Changes

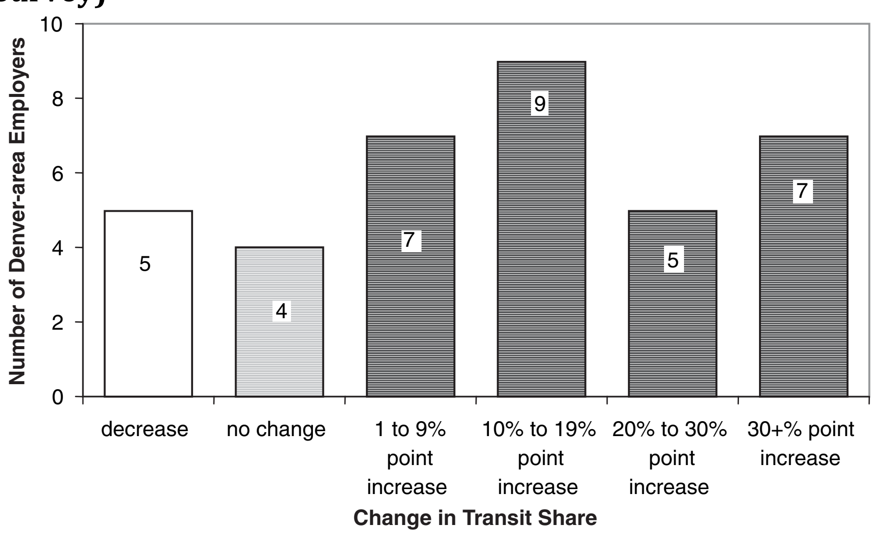
2003 sureys showed an average increase in transit mode share at participating EcoPass employers of 11.7 share points, from 37.7% to 49.4%. Slightly more than 30% of employers increased transit mode share by more than 20 share points, whereas approximately one quarter showed no increase or a decrease. Denver RTD estimated that approximately 15% of the riders participating in EcoPass were net new riders in 1993, and 24% in 2003. This comes from survey data only, from a limited sample with low response rate, so it is hard to know the size or magnitude of the error of this estimate. The expectation is that the above mode share increases are at least directionally correct. The survey results do not indicate if these were the percentage of people who ever took transit, or those who regularly take transit.

In 1993 Denver RTD estimated from its survey that 4.4% of current transit riders increased their frequency of usage after becoming participants in an EcoPass program. Average trips per week increased from 6.6 to 7.8 across all employees in 1993, or about 18%. Since prices don't vary per employer for the Area EcoPass, this implies that either employers joining in the first year are paying 18% too much, or that employers in subsequent years were paying 18% too little. An increase in usage, without an increase in price on a per employer basis, implies that revenue neutrality for each employer is not in effect. It has no implications for revenue neutrality for the program as a whole. The numbers from 1993 are also less applicable to today, since a majority of employers at that time participating in EcoPass were in the Boulder Area, as opposed to Denver CBD.

In 2003, 73% of employees in the Denver CBD reported using transit at least once prior to participation in EcoPass. After EcoPass, 89% of employees reported using transit. This should not be seen as representative, since imputed mode shares based on pricing are only 31% at maximum in the CBD. Based on RTD's estimates of new ridership created by EcoPass, up to 42% of all new riders on Denver RTD from 1997 to 2001 were the result of the EcoPass program. (TCRP Report 107, 2005)

As seen in the figure below, "Number of Denver Employers by Change in Mode Share (2003 Survey)", 75% of surveyed employers reported increases in transit mode share after participating in EcoPass, and almost once third reported increases of more than 20% (of the base, not mode share points). This is a selection of employers from throughout the region, so it is difficult to draw conclusions about the variable success rates from this single measure. Only 5 out of 37 surveyed employers saw a drop in mode share after EcoPass. It is unlikely that EcoPass would be the cause of these decreases. This indicates the year-to-year variability inherent in these measurements, and the difficulty in ascribing change over time solely to programs like EcoPass

Figure A-3. Number Of Denver Employers By Change In Mode Share (2003 Survey)



Source: (TCRP Report 107, 2005)

Appendix 5: King County Metro's FlexPass And The University Of Washington's UPass: Integrated Transportation Benefits

Baseline Situation

King County Metro Transit (KCMT) is the service provider for the 1.7 million residents in the 2,134 square mile Seattle metropolitan area. KCMT began operations in 1973, taking over service from City-run Seattle Transit and the private suburban Metropolitan Transit Corporation. (King County Metro Transit, 2009) In 2007, KCM ran approximately 1,300 buses for 43m miles annually over 9,510 stops, with 111m boardings annually. (King County, 2008) KCMT also operates a vanpool service with more than 600 vans. Annual farebox revenue is $93m; $29m from cash fares, $49m from passes, and $15m from vanpool, paratransit, and other operations. Operating expenses are $461m. Fares are $1.25 off peak, $1.50 for travel in the peak within Seattle or within the rest of King County, and $2 between Seattle and the rest of King County in the peak. Monthly passes are priced at 36 rides for off peak, single zone peak and multi zone peak, or $45, $54 and $72. Annual Passes cost the equivalent of 11 monthly passes. The Link Light Rail system is scheduled to be completed this year running from Downtown Seattle south to the airport. KCMT also operates a "ride free zone" in a small portion of the downtown area.

The University of Washington's Seattle Campus is located in the northern portion of Seattle, with 42,000 students, 4,100 faculty members, and 6,800 non-academic staff occupying over 20m square feet of gross building space. 50 bus routes serve the University District, and 35 are directly on the campus (University of Washington Facilities Services, 2009). Commuter Services owns and operates 11,410 spaces on campus (University of Washington Commuter Services, 2007). The Link Light Rail system will eventually to be extended through the University of Washington campus. (City of Seattle, 2009)

Washington State's Commute Trip Reduction law was passed by the state legislature in 1991 as part of the Washington Clean Air Act. It applies to all employers with 100 or more employees who commute during peak hours in counties with population over 150,000, including King County. The original guidelines called for reductions in VMT against a 1992 baseline of 15% by 1995, 25% by 1997, and 35% by 1999. In 1997, the program was amended to change the reductions to 20% by 1997, 25% in 1999, and 35% by 2005. The law was reauthorized in 2006, setting new goals for 10% reductions in SOV mode share by 2011 against 2007 baselines, and a 13% decrease in VMT (Seattle, City of, 2009). Employers are required to survey their employees biannually, and to report on their CTR efforts on an annual basis. There are no penalties for failing to achieve the goal reductions, but good faith efforts are required. (Washington State Department of Transportation, 2009) Each municipality is required to implement its own specific guidelines, based on the State law. Seattle requires that employers implement at least 2 of a long list of TDM measures, including both transit subsidies and parking cash out, as part of their good faith CTR efforts. (Seattle, City of, 2008)

In addition to the reduction in FICA from the Federal transit benefits program, there are supplementary incentives for employers in Seattle to provide transit subsidies and other CTR measures. Employers save half the subsidy they pay for public transit, up to $60 annually on their Washington State B&O or Utility taxes. Employers can also claim exemption from the annual $25 Employee Hours Tax assessed by the City of Seattle for all employees who commute to work at least 80% of the time by non-SOV modes. (King County Metro Transit, February 2008)

UPASS: HISTORY

The University of Washington's UPass is a Universal Access Pass that allows students to opt-out, and all faculty who do not have parking permits to opt-in. All employees with parking permits are provided with UPasses for no additional cost. As of 2008, UPasses without parking privileges for employees are $23.33 per month; SOV parking with an included UPass is $95 per month; carpool parking is $20.40 per carpool plus the cost of the UPass. Student UPasses are distributed to all students, and cost $16.67 per quarter. If a student returns the UPass by the tuition due date, the fee is refunded. Parking permits are available to students on a limited basis at the employee rate. Both students and employees who have UPasses can carpool on an occasional basis for a significantly reduced daily rate via daily payment at the entrance to specified carpool lots. (University of Washington Facilities Services, 2009) As part of the University Policy Statement. students or employees who engage in sale or transfer of their UPasses "may be subject to action under General Conduct Code or Student Conduct code of University." (University of Washington, 2004)

UPass is part of the Transportation Management Plan (TMP) at UW initially developed under the 1983 agreement between the University and City of Seattle to create a physical master plan that maintains peak traffic at 1983 levels, and limits parking spaces to 12,300 maximum for the campus. Through 1991, the TMP met the terms of the agreement, but parking lots were nearly always close to capacity, and students had taken to parking in surrounding neighborhoods. Furthermore, the 1989 physical development plan called for development of 2.2m square feet of additional space by 2001 (more than a 10% increase) and 4,300 new faculty and staff, the result of which would be an increase in both peak hour trips and parking demand, on the order of 1,780 additional parking spaces.

In 1989, a task force of King County Metro Planners, faculty, students and staff convened. (Williams & Petrait, 1993) KCMT had excess capacity on routes in the University District at that time, and thus had an incentive to work with the university to increase ridership. (Hester, 2004) The task force agreed on the necessity of providing a range of incentives and disincentives to reduce SOV travel to campus, including increased parking prices. They considered a Universal Access program from the outset, but were worried that past Universal Access programs had only been implemented in low transit mode share areas, similar to the issues laid out in Chapter 2. Despite these reservations, the task force presented their recommendation to increase the price of parking and adopt the UPass to the Advisory Committee on Transportation (ACT). ACT is composed of faculty, staff, and students appointed by EVP. The proposal was approved by the ACT and by the KCMT board. KCMT and UW initiated a public information campaign on campus, including widespread distribution of information materials. Multiple student and faculty groups held debates on the merits of the proposal, and a campus-wide forum convened in 1990. (Williams & Petrait, 1993)

Throughout this period there were no cost estimates for the program, only an outline of the program elements: the UPass, increased parking prices, and complementary TDM programs: vanpool, free carpool parking, and guaranteed ride home for employees. In designing the program costs ACT assumed that UW would maintain their current level of transportation subsidy. Parking rates would increase to market rates over the course of two years (from $24 to $48 per month) to cover some of the additional costs, and that the rest would come from UPass revenue. 91% of voting employees and 88% of students were in favor of the program in a campus-wide referendum. 60% of students wanted the program to be optional, and 40% wanted it to be mandatory. Based on this referendum and cost estimates of the program for mandatory and optional elements, ACT recommended to the Board of Regents of the University, the final arbiter, that the UPass be a mandatory program. The Board of Regents decided instead to create a program from which students could opt-out. Initial pricing was set at $6.67 per month for students, and $9 for employees. (Williams & Petrait, 1993)

Initial UPass payments from UW to KCMT were based on existing sales of passes at UW, and estimates of cash fares paid by students and employees. This price was held constant for the first three years of the program at $3.1m annually, after which it was re-assessed. At the same time, the University and KCMT agreed to add 50,000 additional service hours, and split the marginal cost of that service increase 50/50. In 1999, KCMT and UW agreed to switch pricing to a survey based model. Based on these surveys, KCMT estimates the number of trips taken by UW students and employees, and charges appropriately. Because there are no farebox checks with which to validate the information, the estimate is subject to a some margin of error, of undetermined nature. By 2007, the payment by UW to KCMT had increased to $11.8m, due to increased ridership, higher fares, and additional students and employees in the program and on campus. (University of Washington Commuter Services, 2007)

FlexPass: History

Based on the success of the UPass program, and in reaction to the CTR law passed in 1991, KCMT developed a pilot program with 20 employers in 1993 called FlexPass, which also included vanpool and guaranteed ride home benefits. (Hester, 2004) By 2000 there were 122 employers participating with more than 80,000 employees. As part of the program, KCMT requires that employers subsidize at least 50% of the program. As of 2000, 90% of employers subsidized the entire cost for their employees. (TCRP Report 94, 2003) Pricing was based on the required biennial CTR survey. Mode share from these surveys was converted to annual trips, multiplied by the average system fare, weighted by zone and time of day. KCMT reserved the right to increase the price based on surveyed increase in usage annually. The first year increase in transit mode share averaged 90% over previous levels, which proved to be an unworkable increase in cost for employers. To counteract employer dissatisfaction, price increases to reach revenue neutrality were spread out over 4 years. King County Metro was also the recipient of a federal grant over the first 10 years of FlexPass that paid for a 10% discount for employers who participated. (Hester, 2004)

This program was renamed the Custom FlexPass in 1998, and limited to employees with 500 or more employees. At the same time KCMT introduced the Area FlexPass, an attempt to attract more employers without increasing administrative costs. Pricing is calculated based on CTR survey results in each area, with increases based on expected growth. For new participating employers, the expected growth is spread out over the first 2 years of the program, based on the transit mode share of non-participating employers and participating employers within that zone. (Hester, 2004) Annual prices range from $328 to $453 in the Seattle CBD, depending on what transit is included, as of late 2008. (King County Metro Transit, February 2008) KCMT developed 18 separate geographic zones for this program, with 12 of these zones within the City of Seattle. This was in reaction to the issues with adverse selection based on too few geographic groupings that Denver RTD's EcoPass experienced. (King County Metro Transit, 2007)

FlexPass differential pricing was created to appeal to the expected differences in use between downtown and more suburban areas. KCMT believed that the program would mostly appeal to employers in downtown areas, both in Seattle and Bellevue. Instead, it caught on at inception in suburban markets, because of the low pricing and the demand created by the CTR regulations. As CTR programs have become more widespread downtown, participation has increased. In suburban areas the employer subsidy tends to be 100%, whereas downtown employers tend to subsidize closer to the monthly minimum required 50%. (King County Metro Transit, 2007)

FlexPass & UPass: Future Developments

King County Metro is currently in the process of implementing their new SmartCard along with 6 smaller local agencies, the One Regional Card for All (ORCA). Distribution is set to begin late Summer 2009. This will allow significant changes to the FlexPass program. The Business Passport Program will replace FlexPass. Employers will have the option of either the survey-based methodology currently in place, or can pay on a consignment basis based on actual rides. Employers and employees will be able to add other products to the Business Passport program (such as ferries, or a purse for other riders). Account management will move online. Reports will be available to employers on ridership and the status of all cards, but no personally identifiable data will be available. KCMT is discouraging new signups for FlexPass until ORCA rolls out. (King County Metro Transit, 2009)

The ORCA SmartCard project will also be extended to the UPass, but not until 2010 because of integration issues that KCMT expects to be able to resolve once it has rolled out ORCA elsewhere. (December 9, 2008 Minutes; University Transportation Committee, 2008) The intention is to put the chip in the ID card. (October 14, 2008 Minutes) The University has also floated creating a program that it has tentatively called UPass Green. This program would allow limited parking rights and "a few" trips on public transit for a minimal fee per month, as well as access to shower and bike facilities. (July 8, 2008 Minutes)

GOALS

Both FlexPass and UPass are intended to increase ridership and allow employers and the region to meet the CTR goals, while maintaining revenue neutrality. Specifically, revenue neutrality is incorporated into the fare ordinance that dictates the agency's fare policy. UPass and FlexPass required approval by the Metro/King County Council, and an amendment to the KCMT fare ordinance. KCMT defines fare neutrality on a per customer basis, so that any employer participating in FlexPass or UPass should pay as much to KCMT as the agency would have received had the employer paid for their employees transit rides through pass purchases or cash subsidies. (AC Transit Universal Pass Program Questionnaire)

IMPLEMENTATION

The UPass program consists of a sticker affixed to the University ID, which is flashed to the driver. FlexPass is a normal magnetic stripe card, with FlexPass written on it in large type. For large corporate customers, the employer's logo is also on the card. Employees must sign a disclosure agreement that the pass is for their own use only. KCMT can match the serial number back to the employee for those cards that do show up for resale on websites or other forums. (Wong, 2007) King County employees who are eligible for benefits receive a combined identification and FlexPass card, with their picture ID imprinted on it. (King County, 2009) UPass and FlexPass combined required a 2.5 full time employees to administer, as of 2004. (Hester, 2004) By 2007, this had increased to 4.5 employees. (Wong, 2007) Employers at multiple sites receive pricing according to surveys at each site.

Figure A-4. Sample Flexpass Image

UPass information is available in all orientation packets for students and staff. There are fliers mailed out once or twice per year, advertisements in the campus paper, and 9 campus commuter centers to distribute info. For students, the pass itself is part of the marketing for the program, since it is distributed to all students when they first come to campus. (University of Washington Facilities Services, 2009)

PARTICIPATION & RESULTS

In order to draw lessons from an integrated parking and transit program, the remainder of this case study focuses on results from the UPass program. However, the FlexPass program has also been successful. As of 2007, there were 300 employers, with some having as few as 20 employees, and others as many as 25,000. The majority of participating employers have between 50 and 500 employees. This accounted for approximately 120,000 employees, 8m rides, and $10m in revenue in 2007, up from 80,000 participants in 2000. (TCRP Report 94, 2003) Within 3 years ridership at companies has doubled on average, but this metric is heavily weighted to suburban employers. In downtown Seattle, the average increase has been closer to 13% of a base transit mode share of 47%, or 7 transit mode share points. (Wong, 2007) As of 2000, riders who had not previously used KCMT's services took approximately 20% of all trips by participants in the FlexPass program. Renewal rates year-over-year by employers are 95%. (Hester, 2004) Employers often ask for new service as part of the package, but budget constraints prevent KCMT from being able to comply with these requests. According to staffers at KCMT, the program is revenue positive. (Wong, 2007)

Evaluating the success of the UPass program requires establishing that it is revenue neutral for KCMT (per their own defintion), cost effective for UW, and achieves CTR goals. As of 2006, KCMT transit estimated their average fare per trip at $1.39. (King County Metro Transit, 2007) During this same period, the cost per trip for UPass holders was $1.37, based on the annual payment by UW to KCMT transit, and the estimated number of trips annually by UPass holders. Because this is a rough estimate, a differential of less than 2% can be assumed to be more or less revenue neutral. The average cost calculation also includes net new riders. Therefore, KCMT has retained revenue neutrality by their definition for both new riders and existing riders through the UPass program.

COMMUTE TRIP REDUCTION GOALS

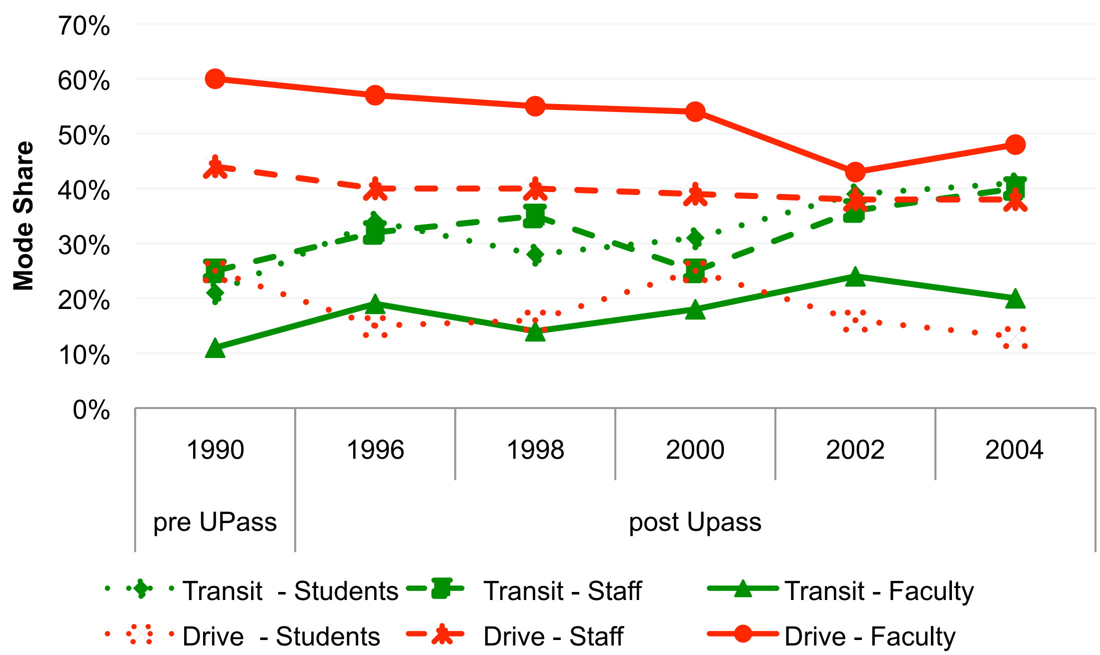
85% of students and 70% of faculty and staff participate in the UPass program, whether through purchase, or along with their parking permit. This ratio has increased for students from 74% at program inception, and from a brief low of 63% for faculty 10 years ago, after initial participation rates of 70%. As part of the CTR program, UW surveys their students, faculty and staff every two years.[23] Since the

[23] Approximately 5% of the population was selected to survey, with response rates in 2006 of 37% within that population overall, but as low as 25% for students Northwest Research Group, Inc. (April 2007). *2006 U-Pass Survey Final Summary Report.* University of Washington / King County Metro .. There is variation between years that may not be significant of actual trends.

inception of the UPass, UW has seen transit mode share increase and SOV mode share decrease for students, faculty, and staff.

A seen in the figure, “Mode Share at UW”, for students, transit has increased by 20 mode share points from a baseline of 21% pre-UPass, 12 of which are from SOV travel, but the other 8 of which do not result in a reduction in SOV trips. For staff, there has been a 15 share point increase in a 25% baseline transit mode share, only 6 share points of which have resulted in reduced SOV travel. For faculty, transit mode share increased from 11% to 20%, and drive alone mode share decreased from 60% to 48%. Drive alone mode share has decreased by a greater total amount than transit usage has increased. This difference is accounted for by an increase in the number of people biking to work. This may be due to the greater location flexibility of faculty because of income, and therefore an increase in the number of faculty who choose to locate within walking or biking distance of UW, or it may be just be the result of changing preferences. By comparison, the total transit journey to work mode share for the Seattle Metropolitan area grew from 6.31% to 6.79% from 1990 to 2000. (U.S. Census Bureau, 1990 & 2000)

Figure A-5. Mode Share At UW



Source: University of Washington Annual Reports, 1996, 1998, 2000, 2002, 2004

The assumption that the decrease in transit fare is responsible for the increase in transit riders, and the increase in parking prices is responsible for the decrease in SOV commuting, allows calculation of demand elasticities with respect to price for individual program elements. Using this methodology, demand elasticity with respect to price for “regular” commuting behavior by transit is -0.46 for students, -0.10 for staff, and -0.06 for faculty, using 1996 mode share. Likewise, for the drive alone mode share, demand elasticities are -0.37 for students, -0.30 for staff, and -

0.79 for faculty. Since most SOV conversion is to public transit, this methodology does not work when there are multiple factors that attract people to transit and push them away from SOV travel. Students face a regulatory system for parking, where not all student demand for parking is met, rather than a price-based system, where all people who want to purchase a pass at a given price are allowed to do so. Fewer than 5% of students had parking permits, even prior to the UPass. Therefore most of the change for students can be ascribed to the "pull" of transit. The "pull" of transit can be discounted for faculty, the high demand elasticity for driving alone ascribed to the availability of other options, such a walking or biking, due to home locations close to campus. For staff, there is less price responsiveness over all, implying less flexibility, but more responsiveness to the "stick" of parking prices than the "carrot" of transit subsidies.

UPass does seem to have increased the variability of the commute to UW. 20% of faculty, staff and students with UPass use multiple modes to get to campus in a given week, but only 9% of those surveyed without a UPass use multiple modes. The group who is multimodal is approximately 60% female, and lives closer to campus than those who use a single mode (9 miles on average vs. 14 miles for those who drive alone only), in contrast to the results from (Rosenbloom & Burns, 1994). Transit mode share is significantly higher for those with a UPass (37% vs. 7%), but this is likely due to self-selection. Measuring by trips, rather than most frequent mode, mode share for transit increase slightly for students (from 41% to 42%) and faculty (from 20% to 27%) and decreases for staff (40% to 37%). 62% of all students rode transit in the last week (21% used it occasionally, while 41% used it primarily), 40% of staff (no non primary use), and 40% of faculty (20% non-primary use). (Northwest Research Group, Inc., April 2007) There are no comparisons to the occasional usage prior to UPass.

In 1992, UW specifically asked people about their usage prior to and after UPass. 46% of those people who used transit infrequently (1 to 5 times per month) before UPass boarded transit at least twice in the week preceding the survey. Of those people who had not used transit at all prior to UPass, 56% used it at least once in the prior week, and 30% were regular transit commuters (at least 5 one way trips in the preceding week). The mean trips per week for these people who formerly did not use transit was 3.3. For those people who had previously been frequent users (5+ trips), 18% no longer used transit, 24% used it less frequently, and the remaining 58% used it at least as or more frequently, for a mean of 8.8 trips per week. These comparisons demonstrate not just behavioral change, but also provide evidence of variability between weeks. The people who formerly used transit frequently, but did not post-UPass, may simply have had an exceptional week, either before or after UPass. They may still have been frequent transit riders.

In 2006, on average, survey respondents with a UPass took 4.13 one-way transit trips during the weekday, and 0.49 trips on the weekend. 3.77 of these trips were to or from the UW campus. In other words, 82% of all trips were commute trips. (Northwest Research Group, Inc., April 2007) 64% of the cost of the transit contract with KCMT is paid for directly by UPass fees, and 28% by parking fees. Therefore, the actual cost to the University of non-commute trip is approximately 18% of the 8% of the program cost that the University subsidizes directly, or less than 1.5%. Use of the Guaranteed ride home program, available only to employees, has decreased from 1 in 64 employees using it annually at program inception to 1 in 163 in 2006-07. (University of Washington Commuter Services, 2007) In other words, it is more the promise of a benefit, than an actual benefit. If the average ride costs $20, then the expected value of this benefit is $0.12 per employee per year.

These changes in mode share also show up in the total number of parking spaces in use. This measure has decreased from 10,742 prior to UPass to 8,040 today. It dropped to about 9,400 immediately following UPass, slightly increased with population until 2002-03, and then started dropping again. The number of parking permits per employee has also decreased from 2 in 5 employees having annual permits prior to UPass to 1 in 5 in 2007. During that time the number of spaces in use per permit has increased from 1.67 to 2.14, and the number of PM peak trips per used space has increased from 0.84 to 1.00. Furthermore the ratio of people who drive alone to the number of permits issued has increased from 1.2 to 2.0. In other words, there has been significant movement to daily parking, and parking off site. This can be seen as an anomaly among the successes of the program; parking demand has not decreased as much as permits. Or, it can be seen as a success; people are taking advantage of the extra flexibility they achieve by combining parking with transit or alternate mode usage, even if they still purchase a parking permit. Increasing flexibility is part of the University's CTR goals in their Administrative Policy statement. (University of Washington Commuter Services, 2007) If the societal goal (rather than the University's goal) is reduced auto use, than flexibility is a tactic to achieve political acceptance, rather than an end goal. If it had not also resulted in decreased auto usage, than it would have backfired.

As mentioned previously, UW does not report the cost of building and operating its parking facilities. However, it does report on overall program costs for UPass, including parking revenue as part of the revenue source. This reporting data is only available starting in the 1999-2000 academic year. From that point on, cost recovery from UPass has increased from 52% to 64%. This seems to be an artifact of a change in accounting. Parking revenue decreased by $1.3m from 2004-05 to 2006-07, despite an increase in permit prices and little change in the number of monthly permits issued. UPass revenue increased by $1.3m during this same time period, despite stability in both the size of the contract with KCMT and the number of participants. It appears that some of the revenue from those people who get a "free" UPass with their parking permit is now being attributed to UPass. The ratio of the price of parking to UPass is approximately 4:1. This is approximately the proportion of revenue formerly attributed to parking now attributed to UPass.

If this was simply a change in attribution, as suspected, then actual cost recovery from UPass is, in fact 64%, and has remained stable. In other words, the University subsidizes 36% of the cost of the transit portion of program, or $4.2m per year in transit costs, and an additional $1m in administrative, shuttle, and carpool costs. By their accounting method the University attributes all but $1m of this subsidy to revenue from parking permits. (University of Washington Commuter Services, 2007) This accounting method ignores the cost of providing parking. With 11,410 spaces currently owned by the university, unless the average annual capital and operating cost per space is less than $350, there is no actual excess revenue from parking. The opportunity cost of the land alone is likely higher than $900 per year, and operating costs are expected to be higher than $400 per year, as per Chapter 2.

COST EFFECTIVENESS

The increase in parking prices at the very least helps cost recovery from parking. Assume that only the initial doubling of prices is apportioned to the UPass program, and that the year-over-year increase thereafter would have happened without UPass. Therefore half of the 36% subsidy is attributed to parking, so that the equivalent University subsidy is actually 18% of the cost of each pass. There is also a $1m subsidy (or 8% of the cost for the transit portion of the program) going to other measures. Over this same time period the University has paid KCMT approximately $131m[24], or $98m in 2006-2007 dollars, taking into account CPI increases. Assuming that the subsidy proportion has been more or less stable since program inception, then the University has subsidized $24m of the transit component of UPass. UW has also spent $14m on other benefits and administration between 1992 and 2007 in actual dollars, and $17m and $11m in real terms.

Apportioning the increase in demand for parking due to UPass throughout the 15 years since UPass began, the program has saved demand for 50,000 parking spaces. From Chapter 2, the marginal cost of constructing parking is $1,500-$3,000 per year in construction costs only, for aboveground structured parking. Even assuming no marginal operating or land costs, this works out to a minimum savings of $940 per space per year, or $47m over the course of the program in 2006-07 dollars, as shown below.

Table A-8. UW Savings From Upass

Parking Demand Reduced (spaces)	50,000
Annualized Capital Cost of Constructing New Spaces	$1,500
Cost of Constructing New Parking	$75,000,000
Transit Subsidy (2006-07 $s)	$17,000,000
Other Program Costs (2006-07 $s)	$11,000,000
Total Savings from UPass	$47,000,000
Savings per Space Saved	$940

Source: (University of Washington Commuter Services, 2007)

[24] Some costs have had to be assumed, based on contextual data, since they were not reported in the annual reports.

As University Transportation Systems Manager Peter Dewey put it:

> The program has allowed us to minimize the use of our parking facilities. We currently have 12,000 spaces, fewer than in 1983, despite 8,000 additional people. Without vigorously managing our parking and providing commute alternatives, the University would have been faced with adding approximately 3,600 parking spaces at a cost of over $100 million. With fewer cars on campus since the inception of U-PASS, the University has created opportunities to make capital investments in buildings supporting education instead of structures for cars.

(King County Dept. of Transportation, 2001)

SATISFACTION

KCMT has increased ridership and revenue, and has also maintained revenue neutrality in terms of average fare per passenger, including net new riders. UW has saved money and not only complied with the CTR ordinance, but is seen as a model employer, having received numerous awards for its innovative program. Participants are also happy. 65% of all respondents to a campus wide survey in 2000 reported that they were "very satisfied" with the UPass program, and an additional 25% reported that they were "satisfied." (TCRP Report 94, 2003) By 2006, this number had increased to 68% very satisfied, and 27% satisfied. (University of Washington Commuter Services, 2007) The program seems to have fulfilled the win-win-win premise of the Universal Access pass concept.

Appendix 6: Other Cities And Projects

Portland TriMet: Universal Access as Part of the Toolkit

Portland is similar to other Western cities, in that there is CTR legislation that requires reducing SOV trips by 10% over a period of time for employers over 50 employees. To track progress the Department of Environmental Quality (DEQ) requires a survey every two years. As long as the employer has a plan in place, they are in compliance with the CTR rule. Portland TriMet, the transit operator in the region, offers a Universal Access pass to help employers meet this requirement. They encourage employers to subsidize the program 100%, but not all employers do so. As of February 2009 there are 228 employers in the program, of which 150 subsidize in full. This covers 60,000 employees and brings in $12m in revenue, or approximately $200 per employee. This represents 16% of total agency revenue. Two thirds of employers are located in the CBD. Program costs are contracted separately with each employer, based on the DEQ survey.

TriMet claims to have maintained net revenue vs. the previous employer program, "pretty confident we don't lose any money," (Strader) but without tracking they have no way of knowing. Costs are reassessed every two years, so in the interim, if the program is successful, there is revenue loss for any net new riders or increased usage among existing riders.

With no AFC system in place, all employees in the program receive a sticker on their existing ID cards. This reduces non-employee use, except when employees simply remove the sticker and give it to someone else. The marketing and sales group at TriMet assists employers with trip planning as well as selling the program, and the agency conducts transportation fairs at employers. (Strader, 2009) If this story seems like you have heard it before, it is because the program is, in a sense, mundane. It is simply part of the employer offerings, and one that is viewed as successful at that. The Lesson: If these programs are implemented well, they need not appear to be revolutionary to either the agency or the employer. Instead, they can be part of the suite of employer programs that help out both employers and riders.

Berkeley & AC Transit: Internal and external political conditions for success

In Berkeley, CA, the University, the local transit operator (AC Transit) and the City collaborated to create a Universal Access program for students called "Class Pass" in 1999. Prior to that, the University had experimented with significant subsidies for transit via an opt-in program, at varying levels from 25-75% subsidy. The University decided that they wanted to move toward a Universal Access pass two years prior to implementation, but needed to negotiate the terms with AC Transit and the City. Each party had an interest in making sure that the deal worked. AC Transit was facing a reauthorization of a sales tax, part of which was dedicated to a significant portion of AC Transit's operating costs. Students make up a large segment of Berkeley's population. AC Transit wanted those students to vote for sales tax reauthorization for transit. They made the connection that support from students would be assured if they all used the system. (Levin, 2000)

Rent control regulations in Berkeley were relaxed in 1998, resulting in an increase in rental prices. This priced many students out of the market near campus, which increased the number of students using cars to commute. The campus is a significant portion of the population in the City; the result was increased congestion and emissions citywide. Thus, the city had an interest in addressing these issues, by moving students away from SOV travel. The University also had significant interest in seeing increased transit use, both because of the traffic impact, but also because the land used for parking was prime real estate for future facilities expansion.

The negotiations ended in a program priced at $10 per semester per student, plus an additional $8 for University services, for a 3 year contract with opt out by either party at any time. This pricing was based on 40 trips per month for current riders, and 20 trips for the projected new riders at "Youth" fares. Students voted to approve the program with an overwhelming 89% margin. (Levin, 2000) In 2006, the program came up for renewal for the second time. Even with prices now at $58.50 per semester 80% of students voted to renew the program. Revenue for AC Transit has increased from $300k annually to $1.3m; approximately 3% of AC Transit's annual fare revenue now comes from a single institution. The major political issue since inception has been that fraud that occurs. Even today, if you search on the Craigslist website you will find multiple ClassPasses (face value over $400) advertised. (Wilcox, 2009) The Lesson: the "Universal" portion of Universal Access passes can be a powerful motivation for the city and the transit agency to work with a University in creating a program to reduce parking demand.

Metro Transit: Baby steps toward Universal Access

Metro Transit, serving the Minneapolis / St. Paul region of Minnesota, has a program that is a hybrid of traditional employer program and a Universal Access pass. Metro Transit has a rather complicated fare structure, with local and express pricing, and peak and off peak pricing, similar to King County Metro. In their employer program they do not require customers to select the ticket type, but instead price the tickets based on the historical distribution of usage of peak, off-peak, and express ridership for the entire region. The program has only a single price. Nevertheless, it is designed to take in the same amount of revenue as would be received if individual employees purchased transit passes. The pass price is not available to anyone but employers. Current pricing is $76 per month, as opposed to $84 for a monthly peak local pass. In a typical employer program the company acts the reseller to whichever employee chooses to participate. With the MetroPass, Metro Transit surveys the employer initially, and charges them only for those cards they expect to be used by regular transit riders. However, they allow companies to distribute as many cards as they want, without additional cost.

Metro Transit formerly adjusted costs annually, but now adjusts every quarter. They believe this gives employers an incentive to expand the program, and employees an incentive to trial transit. There is some evidence to support this belief. Examining the percentage of employees participating in MetroPass as of December 2008—for just the subset of companies who were participating in the program in January 2008—eliminates any growth due to expansion of the number of employers. By this measure, employee participation has increased 12%. This a low estimate, since it also includes an unknown decrease from company turnover during that period.

The program began in 1998, and has expanded to 226 employers as of December 2008, with 166,346 eligible employees using 35,172 cards. This represents approximately $16m of revenue annually, or close to 20% of the agency's farebox collections. The program requires 2-2.5 FTEs to administer, mostly because the administrative burden associated with putting photographs on each card is high. They have recently started rolling out their new SmartCards, and have converted the MetroPass first, allowing quick penetration by a defined population. They are reconsidering the photo requirement, since SmartCards are usually kept in the wallet rather than flashed. This SmartCard transition has also enabled Metro Transit to begin thinking about a Universal Access / Pay-per-ride hybrid, that is by definition revenue neutral.

In the short term SmartCards have allowed them to track usage of MetroPasses, which average 30 rides per month. Monthly passes are priced at 35-38 rides per month, but because of the low penetration of SmartCards, there is no data available on average usage. That is, they know that on average MetroPass is revenue positive compared with cash fares, but they cannot make the same conclusion for regular monthly passes. As of December 2008, 19% of employers offer full (100% of the pass cost) subsidies to their employees, 43% offer partial subsidies (subsidized 57% on average), and the remainder do not subsidize. Taken as a whole, the average employee price is $43 for the $76 valued pass. (Personal Communication with Metro Transit Minnesota, 2009) It is likely that these subsidies are one of the reasons that the program is revenue positive for Metro Transit. Subsidies encourage employees who use the pass less than the face value to participate. Lessons: Even for transit agencies that are not ready to move toward Universal Access passes, by aligning incentives for net new ridership between the transit agency and the employer, ridership gains can be achieved. SmartCards allow tracking and measurement, that can advance the case of more innovate employer programs within transit agencies.

Appendix 7: Modeling Mode Choice Variability At MIT

Model details

Chapter 6 used indicators of mode choice on each day of the week derived from the survey responses by the sample to investigate variability in employee's weekly commutes. There are 3 key advantages to this measure: (1) there are many different variations on mode choice, for example between walking and driving to public transportation; (2) it allows comparison to prior years; (3) it permits the largest possible sample. However there is also a major drawback to this measure. Week-to-week variability is significant. People who drive 4 days and bicycle one day this week might drive 5 days next week; some people work from home occasionally on Fridays; etc.

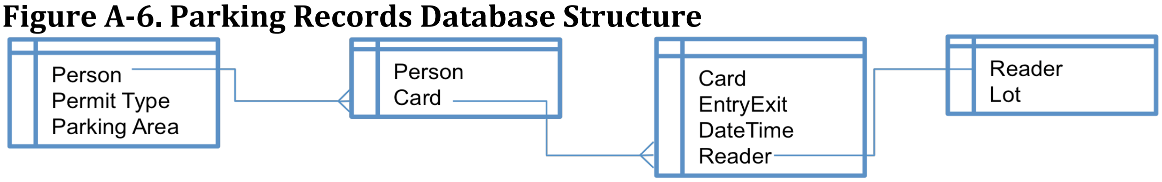
The advantages that weekly mode choice has in providing insight into behavior are not as necessary for a model whose goal is the comparative contributions of choice attributes to the choice of total number of trips to MIT by mode. And the drawback is quite possibly insurmountable. A model based on weekly trip totals makes the implicit assumption that the week in question is representative of other weeks. The literature review in Chapter 2 and the analysis in Chapter 6 demonstrated that there is significantly less variability between sample periods in a multi-week sample.

The model presented below is thus based on two measures: (1) The number of days in October 2008 that the person was recorded as parking at MIT; (2) The number of monthly trips they took on the MBTA, based on the self-reporting boardings by route over a two-week period. For this to be a valid measure this sub sample must be representative of the population, and variability in these measures between months must be low. Both of these tests are examined in depth in the remainder of this appendix.

Days parked at MIT

The available data includes parking records at MIT for September, October, and November 2008, stripped of all identifying information except for a unique identifier that allows each record to be connected to a survey respondent. Each record contains the card number of a card or hands free access device used on a particular card reader, whether the use represents entry or exit, and the date and time. Those card readers are associated with a parking lot. The card itself is associated with a person, who is in turn associated with a type of permit, and an assigned parking area. The full structure is show in the Figure below.

Figure A-6. Parking Records Database Structure



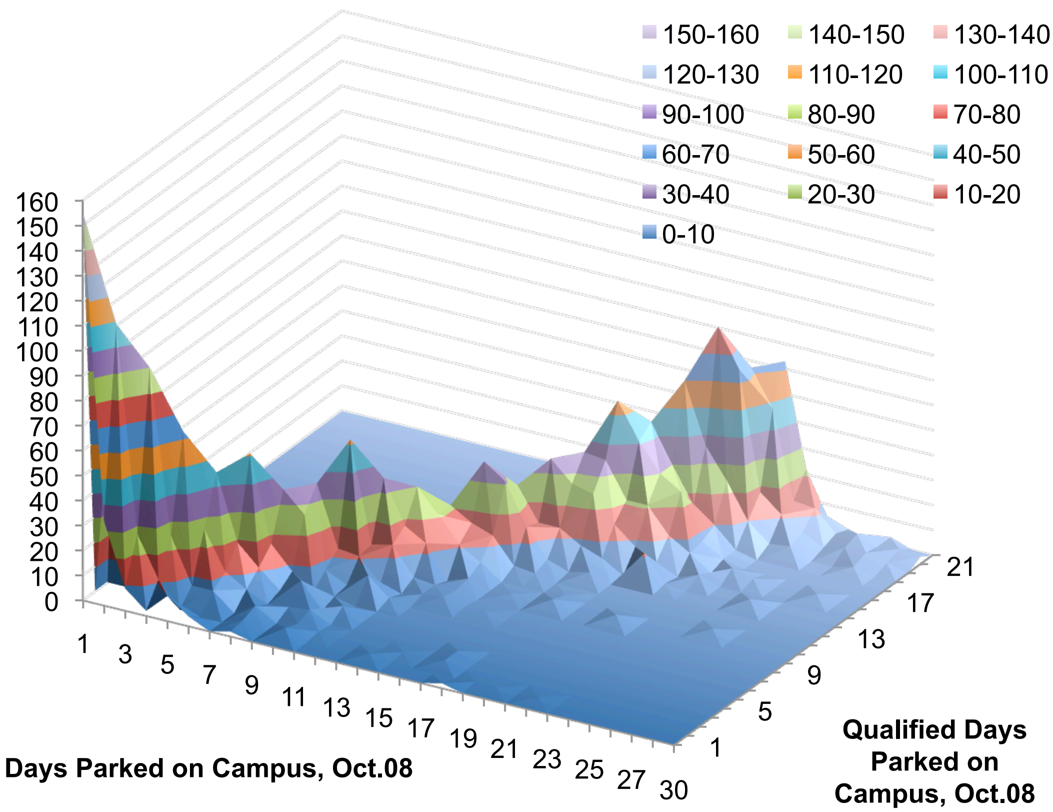
These records are not 100% aligned. There are cards that are not associated with someone who participated in the survey. There are people who gained access who do not have a current record of a parking permit. However, these concerns are relatively minor compared to the larger issue that there are missed entries and exits. For example, if a gate is up, and someone simply drives in, there is no record of entry. If the gate is up when they leave, there is no record of exit. There are also parking lots that are relatively small, or are located in areas where there are no card readers. For these lots there is never a record of entry or exit. If someone is allowed to park in an area that contains one of these lots, they may park more than measured through card access records.

The first type of error is random error. If the gate was simply malfunctioning, or left up for an hour or two to accommodate special circumstances such as construction vehicles, it is possible to infer entry from the exit date and time, and likewise for exit from entry date and time. Since there is only a single charge per day, this is a relatively accurate algorithm. It assumes that the missing entry or exit took place on the same day, 8 hours prior to or subsequent from its companion exit or entry. This does undercount those people who park multiple days without removing their car from the lot. However, from anecdotal evidence reported by the parking office, the number of people engaging in this behavior is minuscule. This measure can apply to both Occasional Parking Permit holders and monthly permit holders, even though the latter is not charged on a daily basis.

The 8-hour assumption is made to distinguish total days parked on campus from qualified days. Total days are a summation over a month of the binary decision of an employee to park on campus on a given day. Qualified days refine this measure to only count those days when an employee parks during the period for which MIT charges. MIT does not charge people who pay on a per-day basis who enter after 2:30pm and leave before 7am on weekdays, or any time on weekends or Institute holidays. Thus the 8-hour assumption allows inference of not just the day that someone parked, but whether it falls within the chargeable window. This allows MIT to offer low cost parking to second-shift employees, when the parking lots are not in use. This second indicator is used in the model; it measures the use of parking when the space in lots is constrained. It is this maximum load point that is costly to MIT. Parking at other times is essentially costless to MIT[25], since enforcement is controlled automatically. The figure below, entitled "Qualified vs. All days parked on campus, October 2008" shows that these measures are highly correlated.

[25] Of course, from the societal point of view, auto use during these off-peak times still generates environmental costs, but MIT's institutional interest is to fully use the parking resource in order to maximize employee satisfaction, and example of the divergence between institutional and societal goals.

Figure A-7. Qualified Vs. All Days Parked On Campus, October 2008



The systematic error that exists in parking records is due to areas where there are lots that are un-gated, whether intentionally or because of consistent usage by construction vehicles. In these areas parking records will neither provide an accurate measure of how often people park, nor is there a means of inference. Eliminating this error requires removing those people who park in these areas from the sample. Because some of this error is "accidental"—rather than by policy—those lots cannot simply be identified through anecdotal measures. Instead, they can be determined by the distribution of how many people who are allowed to park in these areas actually have parking records. Because of inherent variability in travel demand, there is no expectation that 100% of all eligible parkers in an area actually park there in a given month. This thesis uses the appearance of 80% of the eligible parkers in a given area as the cutoff for determining that a card reader is functioning and the gate does not display systematic error, as shown in the table below, entitled "Recorded Lot Usage, Employees, Unweighted, October 2008." Because of the extent of variability in parking demand, a similar methodology cannot capture systematic error for people who have Occasional Permits. Instead, the same lots for which there is no systematic error for monthly permitholders are used for Occasional Parkers. This removes less than 7% of the sample of Occasional Parkers.

Table A-9. Recorded Lot Usage, Employees, Unweighted, October 2008

Parking Area	Assigned to Lot	Record of Parking in Lot	% with Record	Average Uses	Exclude from Sample
Amherst	2	0	0%		Yes
Eastgate	1	1	100%	3.00	Yes
Hayward	49	2	4%	2.00	Yes
Kendall	0	0			**
Kresge	31	6	19%	4.00	Yes
Main	51	47	92%	12.83	
North	295	242	82%	11.49	
Northeast	387	369	95%	12.33	
Northwest	15	15	100%	11.53	
Off Campus	414	12	3%	3.25	Yes
PFC	8	0	0%		Yes
Riverside	155	89	57%	6.89	Yes
Sloan	39	0	0%		Yes
West	229	215	94%	9.51	
Westgate	7	2	29%	1.50	Yes
Total	1684	1000	59%	10.84	

** Recorded 78% of Occasional Parkers in this Lot, so not excluded from sample

The implicit assumption is that the people in those lots that do not show systematic error have the same behavior and characteristics of those people who park in lots that do show systematic measurement error. Weekly mode share measures from Chapter 6 allow a check for bias in the new sample, as shown in Table A-10. The samples are very close to identical. The restricted sample contains fewer people who drive every day, but almost the same number of people who drive some or most days. It is also slightly skewed to rideshare, but not in a manner that is statistically significant. As shown in the tables below, the restricted sample represents a filter of the original sample. It reduces the total sample size, but does not introduce additional error by technique.

Table A-10. Weekly Mode Share For Monthly Permit Holders In Modified Sample Vs Complete Sample, Weighted, 2008

		Complete Sample	Modified Sample
Drive Alone	Only	71%	65%
	Ever	80%	78%
Transit	Only	2%	2%
	Ever	6%	7%
Rideshare	Only	11%	13%
	Ever	17%	21%
Pedestrian	Only	2%	1%
	Ever	4%	5%

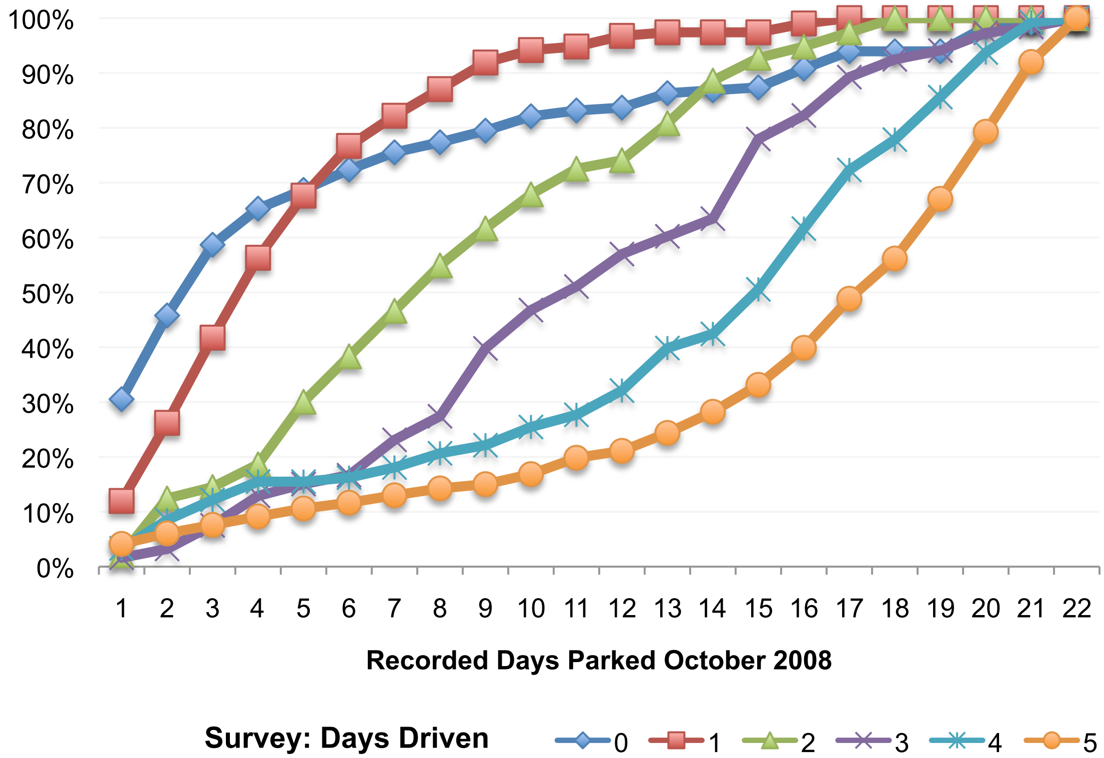
Another check is intensity of usage by those people who are in the sample, as shown in Table A-11. Comparing the number of times they reported driving or carpooling to MIT in the past week against the number of times they parked at MIT in the past month, allows a sense of the difference between the two measures. This is not an indication of variability per se. While differences could be a measure of variability, they could also represent error introduced by self-reporting, or the methodology for measuring actual behavior.

Table A-11. Days Driven In Prior Week For Monthly Permit Holders In Modified Sample Vs Complete Sample, Weighted, 2008

	Excluded From Sample	Included in New Sample
0	20%	22%
1	4%	5%
2	3%	5%
3	8%	8%
4	13%	15%
5	51%	46%

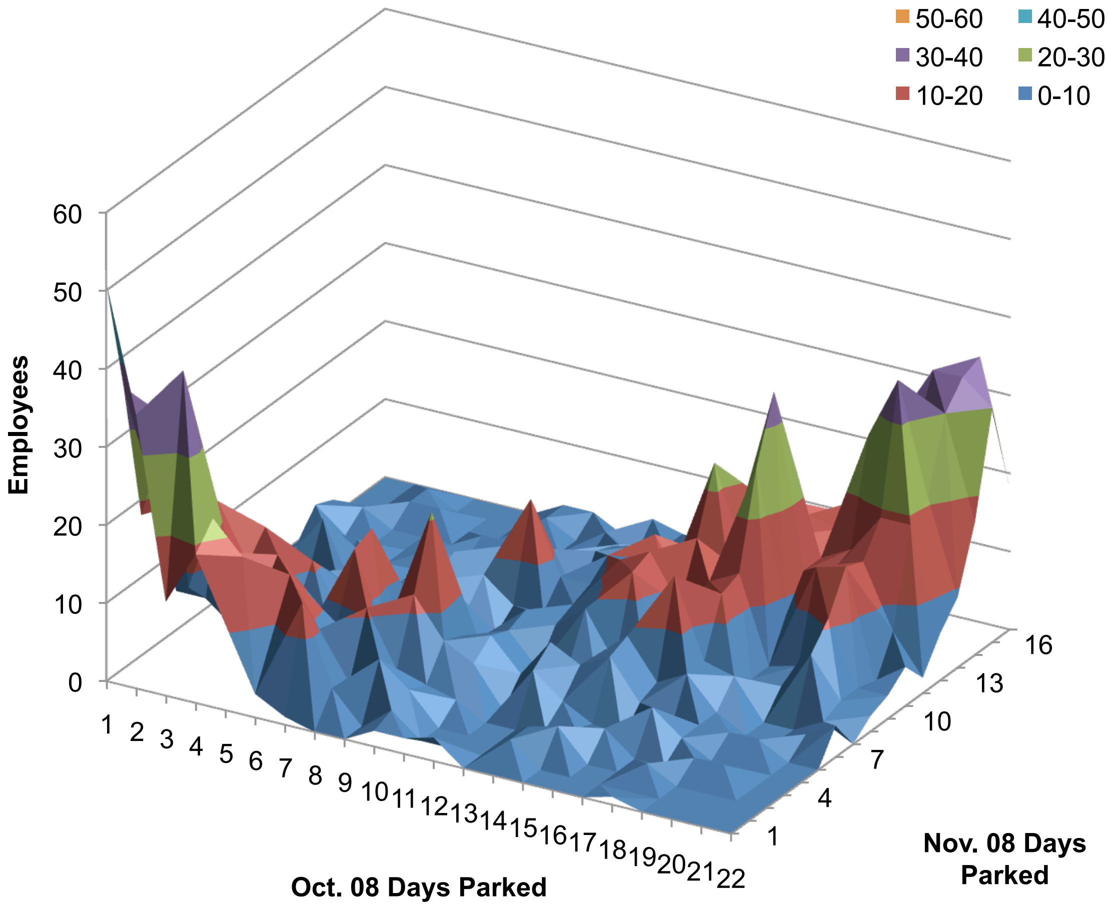
Looking at the percentage of the population who report driving to MIT 5 days in the week, but parked fewer than 5 days in the month in the figure below entitled "Cumulative Density Function of Qualified Recorded Days Parked by Days Driven from Survey" shows that there is still some error in this measure. This amounts to 10% of the every-day drivers. However, not all of this error can be attributed to mis-measurement. For example, those people who reported driving 5 days, but have 1 recorded parking day, could well have parked on the street or in a private lot, or have arrived earlier or later in the day than a qualified parking trip.

Figure A-8. Cumulative Density Function Of Qualified Recorded Days Parked By Days Driven From Survey



This measure does not show significant variability between months. There is between 77% and 82% correlation between months in the number of days people park, for months during the semester. The figure below entitled “Qualified Days Parked in October vs November 2008“ shows that the bulk of people parking are arrayed in a straight axis from the origin where the employee parked once in each month, to the right, where the person parked the maximum number of days in both months. Maximum qualified days varies by month. If the correlation were lower, more samples would appear in the upper left and the lower right portions of the figure. That people with these patterns are not prevalent indicates that variability is more likely to be actual difference in behavior between months, rather than measurement error.

Figure A-9. Qualified Days Parked In October Vs. November 2008



TRANSIT TRIPS TO MIT

No direct measure is available for transit trips. However, the survey does ask for the number of times boarding each of the 4 main MBTA subway lines, the Commuter Rail, 10 specific bus routes that run in the vicinity of MIT, and a catchall for the remaining MBTA bus routes. Respondents were asked to indicate how many times they boarded those routes both in the week immediately preceding the survey, and in the week prior to that. This removes some of the variability associated with a one-week sample. To convert this to a 31-day estimator for the month of October is simple multiplication of two-week total by 2.2.

To make this measure usable requires convert boardings to trips. In a survey that asks for aggregate numbers—rather than travel diary—boardings allow a more accurate description of actual behavior. There are multiple algorithms for converting boardings to linked trips without knowledge about origins and destinations, based on assumptions about behavior.

1. Each trip starts or ends at the home location, at the same stop. The route with the maximum number of boardings in the week is therefore the actual number of linked trips.

2. Each trip has no transfers. The total number of trips is then additive.
3. Each trip has exactly one transfer. The total number of trips is thus exactly ½ of the total number of boardings.
4. Each trip has an X% chance of having 1 transfer. This thesis uses the ratio of boardings to linked trips in the entire MBTA system to find X. Thus the aggregate number of transfers is accurate, so long as people commuting to MIT transfer in the same ratio as the system wide average.

Adding to the complications, there are 3 ways to calculate the number of transfers by this final methodology. Given an infinite number of routes with non-zero numbers of trips in a given week for a given person, these three methodologies, "Average," "Start Min" and "Start Max," converge to the same result. However, convergence does not occur with real data. The algorithm that best meets the inference about behavior must therefore be chosen.

1. In the "Average" algorithm, the sum of boardings across all modes is divided by the ratio of boardings to linked trips for the system as a whole. Linked trips are then the maximum of this number and the boardings on the route with the maximum trips, to correct for those people who infrequently transfer.

2. The "Start Min" Algorithm begins with the route with the minimum number of non-zero boardings. The full number of those boardings is added to running total of trips. Move to the mode with the second least number of trips and take 1-X% of those boardings as new trips, where X is the percent of trips that have transfers system wide. The remainder (X%) are transfers from the previous mode. Those new trips are added to the running total of trips. Move to the next route and add $1\text{-}X\%+(X\%)^2$ of those boardings as new trips. The extra term corrects for the double counting of transfers. Repeat, with an additional polynomial for each route with non-zero boardings. In essence, this assumes that the route with the minimum number of boardings is the most likely to be a unique trip, while the route with the maximum number of boardings has the closest to the system wide average of transfers.

3. The "Start Max" algorithm is similar to the "Start Min" algorithm, except that it begins at the route with the maximum, rather than the minimum number of boardings, and proceeds downward. This leaves a higher number of total trips, and the assumption that the route with the maximum number of trips is not involved in any transfers.

Both of these algorithms can be expressed mathematically, demonstrated in the equation below.

Equation A-1. Boardings To Trips Algorithm For "Start Min" And "Start Max"

$$\sum_{1}^{n}\left(\left[\sum_{1}^{n}(-k)^{n-1}\right]x_n\right)$$

k is the percentage of trips on the system that have transfers (equal to one minus the ratio of boardings to linked trips).

Routes are ordered by number of trips taken in the last week.

n=1 is the mode with the minimum number of trips (greater than 0) for the Start Min algorithm, and conversely is the mode with the maximum number of trips for the Start Min algorithm.

x_n is the number of trips taken on mode n

Comparing these methodologies for two patterns, as in Table A-12 below, allows a sense of the results they provide. The first pattern is one where it seems easy to infer intent. There is a daily commute trip, and one other round trip, which may or may not have been tacked on to a commute trip. There are therefore either 10 or 11 trips. The algorithms vary significantly in their inference about this pattern. The first two methodologies, both of which are clearly faulty from a behavioral standpoint if taken across the population, are much closer to what seems to be the true pattern. The remaining indicate that there at least 14 trips, which is unlikely, although not impossible.

Table A-12. Comparison Of Algorithms

Methodology	Pattern	
	10-10-2	7-5-2-1
Absolute Min	10	7
One Transfer Min	11	8
Start Min	2+.5*10+.75*10=14.5	1+2*.5+5*.75+7*.625=10.1
Average	(10+10+2)/(1+.5)=14.67	(7+5+2+1)/(1+.5)=10
Start Max	10+.5*10+.75*2=16.5	7+5*.5+2*.75+1*.625=11.625
Absolute Max	22	15

The second pattern is more complicated. Is there a dominant route with different destinations? Was there walking involved to make the pattern uneven? Is there a different method of travelling back? It could represent 8 trips, using different combinations of routes (with a single transfer for each trip), or 15 trips, if each boarding represented a linked trip. The algorithms indicate there are between 10 and 12 trips, whereas common sense places the range of trips somewhere between 8 and 10 (5 linked trips using the top 2 routes plus somewhere between 3 and 5 trips using the remaining 2-2-1 pattern). No matter the algorithm it will not match behavior exactly. The question is then which method is likely to be the most accurate.

In the summary statistics in the table below, more than 50% of respondents have one or fewer routes. For all these respondents, the inference about the number of trips will be correct, no matter the algorithm chosen. There are a number of respondents whose answers were clearly outside the bounds of reason. They answered the maximum number of trips allowed by the survey for all or multiple routes for the week's behavior. These respondents (less than 2% of the sample) are excluded for analysis purposes, since any inference about their behavior is likely to be wrong – they have either misunderstood the question, or intentionally provided nonsensical answers. As seen in Table A-13, for the remaining respondents, there is an approximate 50% spread between the highest and lowest algorithms, and that the spread increases as there are more routes and more trips. Because neither the behavioral inference for the Absolute Minimum or Absolute Maximum algorithms is particularly well suited to describe reality, the choice is between the remaining 4 methodologies. There is a 20% spread on average between these methodologies. They are they same for the 50% of people with 1 or fewer routes, increasing to a 10% spread for the 60th percentile, and a 20% spread for the remaining.

Table A-13. Summary Statistics For Trip Algorithms

	Routes Answered	Absolute Min	One Transfer Min	Average	Start Min	Start Max	Absolute Max
Mean	1.44	4.88	5.53	5.85	6.13	6.52	7.74
Std. Dev.	1.459	5.345	6.342	6.831	7.098	7.703	9.693
COV	1.01	1.10	1.15	1.17	1.16	1.18	1.25
Minimum	0	0	0	0	0	0	0
10th Pctl.	0	0	0	0	0	0	0
20th Pctl.	0	0	0	0	0	0	0
30th Pctl.	0	0	0	0	0	0	0
40th Pctl.	1	2	2	2	2	2	2
50th Pctl.	1	3	3.6	4	4	4	4
60th Pctl.	2	5	5.4	6	6.03	6.03	7
70th Pctl.	2	8	8	8.71	9.04	10	10
80th Pctl.	3	10	10.2	11.38	12	12.53	14
90th Pctl.	3	12	14	14.73	15.54	17.06	21
Maximum	13	21	94	105	106	110	157

This thesis uses the "Start Min" methodology as a point estimate of the number of trips. It best matches the author's intuition into how multiple trips are linked. Trips that are outliers (those at the minimum) tend to be unlinked trips. For people who use multiple routes those at the maximum tend to be the linked trips. To modify this measure Commuter Rail boardings are not included in the calculation of linked trips, under the assumption that all trips on Commuter Rail to MIT require a transfer of some sort. While this is not 100% accurate (people can take the EZ Ride shuttle), this inaccuracy can be corrected by taking the maximum of the number of trips on Commuter Rail and the results of the Start Min algorithm. Thus, each Commuter Rail boarding represents at least one trip, but does not add to the total number of trips if it is apparent that there were transfers.

Total linked trips and costs derived from those linked trips, while stated as point values, should be considered ranges, with the likely values some where between the one transfer minimum and start maximum algorithms (plus/minus 10%). Additionally, this measure suffers from recall error. Respondents may not remember their trip pattern for the preceding week (or two weeks) exactly, and thus may inflate or deflate the total number of trips they took on each combination of modes/routes, or simply apply a multiplicative factor to the number of days they commuted. Respondents may also inflate their responses, to seem "more green" or because "last week was atypical." Lastly, many respondents may skip this question. Throughout this thesis the assumption is that those respondents who answered at least one of the questions regarding total weekly transit boardings (zero or otherwise) intended to answer the other routes as having no trips, and did not do so in order to save time. All other non-responses to this question are assumed to be inadvertent, and those people excluded from the sample. This excludes 5% of the sample.

The measure of linked transit trips diverges from the parking measure in that it is not a measure of days commuted to MIT, but instead overall one-way linked trips, including non-commute trips. This rationale for using this measure as opposed to a direct measure of commute days is described in more depth below. Commuting behavior for auto, transit, and for alternative modes that do not show up in the two measures—walking, biking, parking elsewhere, being dropped off, working at home, etc.—is of interest. Comparing linked trips for the month of October to the survey response of the number of days the respondent reported commuting to MIT by transit in the week preceding the survey establishes the approximate percentage of trips that are for commuting. As with the similar comparison for parking and driving, there are two sources of variability here. The surveyed week may have been atypical for the commute trip, but typical for other trips, or vice versa. Furthermore, the number of trips in the secondary week may be significantly different than the trips in the first week.

The patterns below show that there is a clear linkage between the number of transit trips in the month, and the number of commute trips to MIT via transit in a week, but that the relationship is not exact. Per the regression results in Table A-14, the number of days the employee indicated they commuted in the previous week to MIT by public transit explains 71% of the variation in the total number of trips by public transit in October. By these results, each additional commute day represents an additional 10 trips via public transit. For those people with no transit trips, there is an average of 7 non-commute one-way trips per month, while for people who commute by public transit 5 days per week there are on average 13 non-commute trips per month. Overall, each daily commute trip by transit represents 12.3 one-way monthly transit trips. Inferring the number of commute days from the number of overall transit trips is thus well bounded, but there is room at the margin for interpretation.

Figure A-10. CDF Of Transit Trips In October 2008 By Weekly Commute Days Via PT To MIT, Employees, 2008, Unweighted

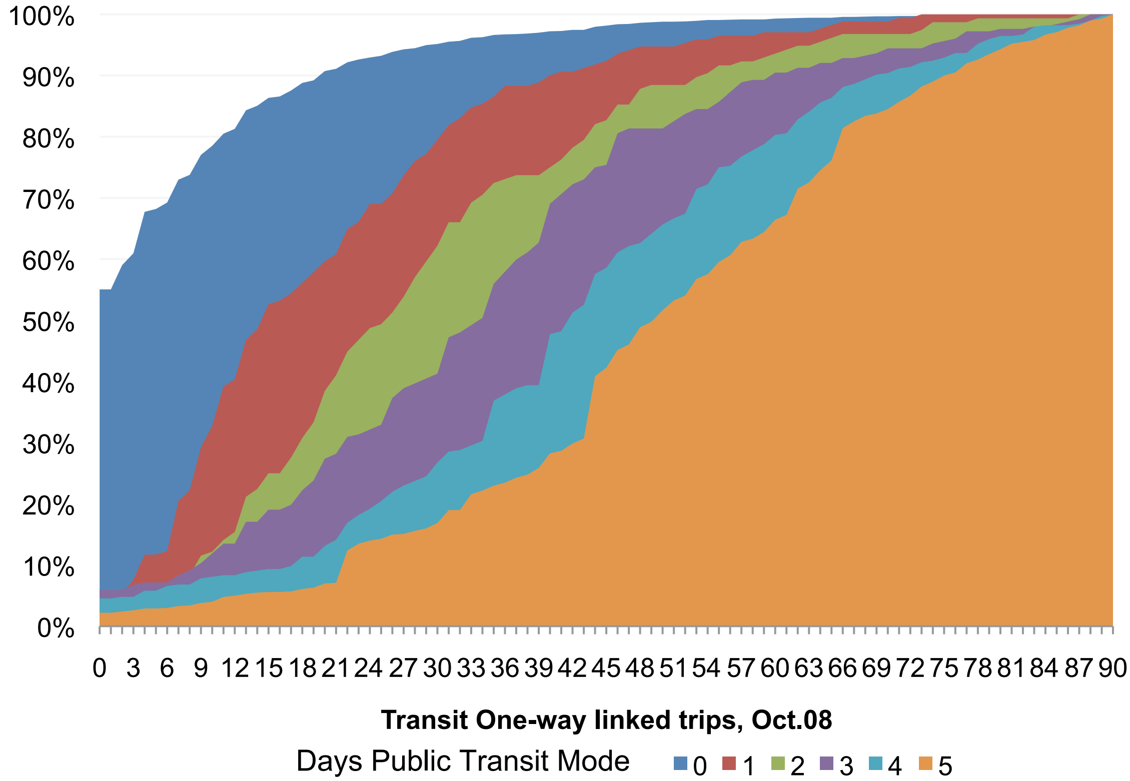


Table A-14. Regression Of Weekly Commute Days Via PT To MIT And Monthly PT Trips

	B	Std. Error	t	Sig
Constant	7.189	.448	16.055	.000
Commute Days to MIT by Public Transit	9.968	.151	66.131	.000

R-Squared: 0.71

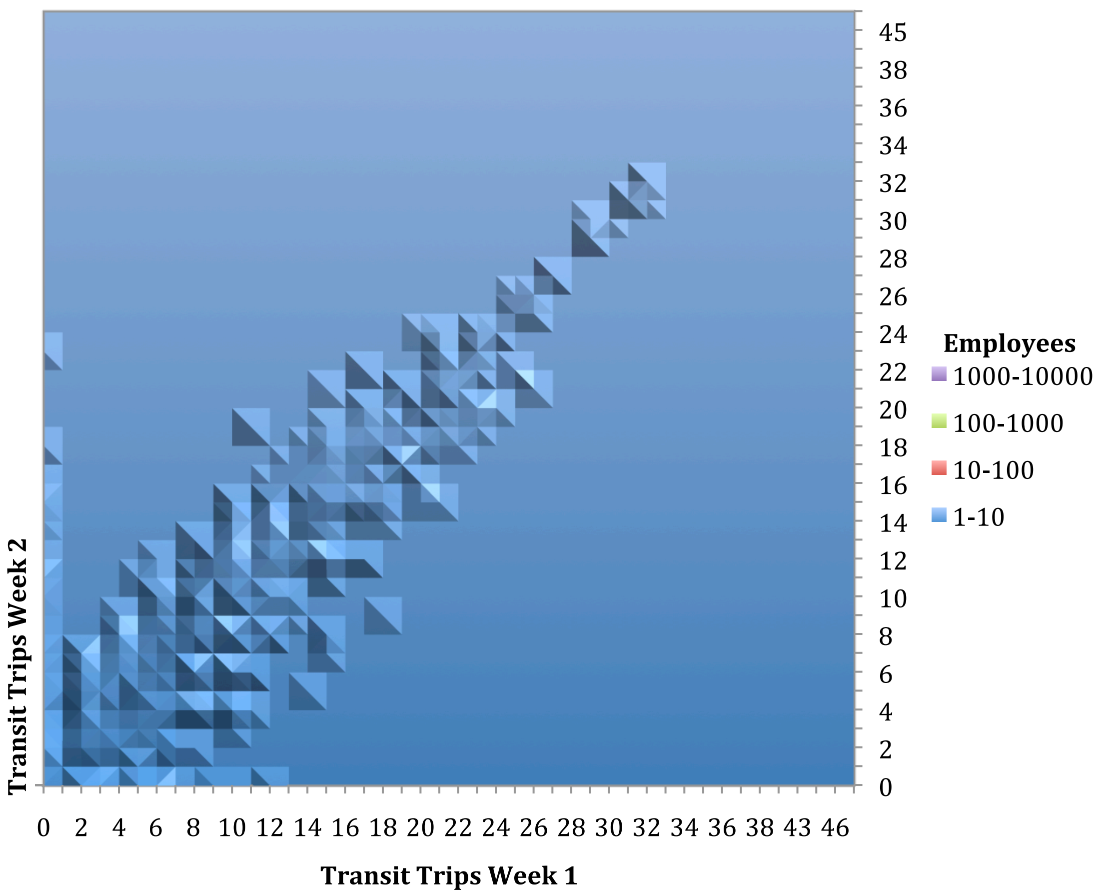
Furthermore, by Table A-15, 45% of people who did not indicate that they took a commute trip via public transit in the week prior used transit during the month. Those people took on average 6.4 one-way trips per month, with 10% taking 20 or more trips. Similar to the regression results above, there are approximately 5-6 non-commute monthly public transit trips at the 50th percentile, regardless of the number of commute trips by public transit. The distribution of monthly transit trips within each category of weekly commute trips by transit is approximately normal, with a slight skew toward the upper end.

Table A-15. Monthly Trips By Public Transit Distribution By Weekly Commute Trips On Public Transit, Employees, Unweighted, 2008

Weekly PT Commute Trips	0	1	2	3	4	5
Average PT Monthly Trips	6.38	19.87	28.53	33.97	42.59	49.72
25th Pctl.	0	8	16	19	29	38
50th Pctl.	0	14	25	33	41	49
75th Pctl.	8	27	40	44	55	64

Data for second week of transit trips is also available, collected via the same means and on the same survey as the first week. Per the figure below, weekly trips are highly correlated between weeks, but not 100% so. Looking at the edges of the figure shows that there is a degree of variability between weeks. Combining these two samples will thus better represent actual travel patterns.

Figure A-11. Week To Week Correlation Between One-Way Transit Trips, Employees, 2008



Discrete vs. Discrete-Continuous Models

The goal is to model the joint decision of trips not by two modes, but by three. That is, this thesis is interested not only in total trips on transit and driving commute trips, but also the implicit number of commute trips taken via non-motorized modes. Because only driving and transit trips are available this requires inference about the number of commute trips each of these indicators represents. Assume a set number of commute trips during a period that cannot be exceeded (20). With only two indicators (PT and AUTO), the third indicator is the remainder of the maximum number of trips in the month minus the total trips in the first two modes (20 – PT – AUTO). However, this is complicated by the fact that only the driving trip indicator is limited to the maximum number of commute trips in the month.

The Commute Equivalent Trip (CEQT) overcomes this limitation. CEQT is an approximate measure of the monthly commute trips by a specific mode. For drive/parking trips, this is a direct measure. For transit trips, it is based on the earlier finding that there are approximately 12 monthly one-way linked trips on transit for 1 weekly transit commute trip. Assuming a 20-day month permits inference about the number of non-measured trips. It is simply 20 minus the measured number of days parked at MIT, minus the number of CEQT by transit.

By definition, any combination of trips by two modes is a discrete choice of the number of commute equivalent trips in a month by the 3 modes of interest. This measure is scaled so that there are between 0 and 20 CEQT in a month for each mode, with a constraint that they add to 20. Handling these constraints could be done via constrained multivariate regression or a discrete-continuous Random Utility Model. This thesis takes a slightly simpler tack, instead modeling the choice of the combination of these trips by mode, categorizing the trips by each mode into 1 of 5 categorizing – 0 CEQT; 1 weekly CEQT (1-5 monthly trips), 2 weekly CEQT (6-10 monthly trips), 3 weekly CEQT (11-15 monthly trips), and 4 or more weekly trips (16+ monthly trips). By these definitions there are 15 discrete combinations that add up to 20 CEQT, and an additional 10 combinations where drive and transit trips add up to more than 20 CEQT. Because these implicitly include non-commute usage of transit, these choices are included in the model as well, as shown in the table below. By creating discrete variables the number of outliers is reduced systematically without making an inference about their meaning. It also allows us for simplicity of interpretation. (Train, 1986) defines discrete choice models as being applicable to "situations in which a decision maker can be described as facing a choice among a finite and exhaustive set of mutually exclusive alternatives." The model described above seems to meet that test.

Table A-16. Number Of Implicit Non-Measured CEQTs*

	Transit				
Parking	**0**	**1 -5**	**6-10**	**11-15**	**16-20**
0	16-20	11-15	6-10	1-5	0
1-5	11-15	6-10	1-5	0	0
6-10	6-10	1-5	0	0	0
11-15	1-5	0	0	0	0
16-20	0	0	0	0	0

* Implicit non-measured commute equivalent trips includes trips by walking, biking, parking at non-MIT lots, and rideshare or drop offs, as well as vacation days, days worked at home, and other non-measured activiteis.

The final break point is for those people who use the mode for at least 16 commute trips via auto, or 36 trips via transit. Those 36 trips for transit correspond to people who use the system at the fare value of a full fare LinkPass. Both of these topmost groups are people who use the mode everyday, or almost so. Creating this break point for transit allows reduction in the variance from the outliers on the high side. With three equal interior periods there are 5 categories for each mode. The equivalent conversions from parking events and transit trips to CEQT are shown in Table A-17.

Table A-17. Commute Equivalent Trips Conversion To Transit And Parking

CEQT	Monthly Transit One-Way Trips	Qualified Days Parked at MIT, October 2008
0	0	0
1-5	1-12	1-5
6-10	13-24	6-10
11-15	25-36	11-15
16-20	37+	16+

SAMPLE DESCRIPTION

Based on the methodology described above, Table A-18 reports on the percentage of employees who appear in each of the 25 categories. Less than 8% of the observations represent purely non-commute transit travel. As expected, there are fewer people who are in the "midpoints" of travel via transit and auto then there are on the end. Similar to the findings in Chapter 6, 22% of employees demonstrate multimodal behavior.

Table A-18. Mode Share By Choice, Modified Sample, Weighted, 2008

	Transit CEQT					
Parking CEQT	**0**	**1 -5**	**6-10**	**11-15**	**16-20**	**Total**
0	6.7%	6.9%	6.6%	5.0%	29.3%	54.4%
1-5	2.4%	1.6%	1.4%	1.3%	3.8%	10.5%
6-10	1.7%	0.6%	1.0%	0.6%	0.9%	4.8%
11-15	2.7%	2.4%	0.3%	0.2%	0.2%	5.9%
16-20	17.0%	5.3%	1.6%	0.3%	0.1%	24.3%
Total	30.7%	16.8%	10.9%	7.4%	34.3%	

To find average CEQT by mode per month requires assuming that total commute roundtrips are equal to the equivalent midpoint of the category, so that for example, the 3rd category (6 to 10) is the equivalent of 8 commute trips. This allows direct comparison of usage between modes. Mode shares, as presented in Table A-19, are very similar to what was found in the Chapter 6. The basic check of whether this measure is a good representation of the actual mode share by the population at MIT is satisfied. Average trips per month by people who have at least 1 drive trip is slightly higher than the commensurate measure for people who took transit, and approximately 20% higher than the average monthly trips measure for those employees who were not on campus, were dropped off, or used non-motorized modes for their commute. This is, in essence, a measure of the consistency of behavior. The measures reported here are used in Chapter 7 for policy comparisons.

Table A-19. Baseline Mode Usage Statistics, Modified Sample

	Transit	Drive	Non-motorized or Not on Campus
% Who Use Mode	69.3%	45.5%	64.4%
Total Monthly Trips	71621	49198	29508
Mode Share	47.6%	32.7%	19.6%
Trips / Person / Month	8.51	5.84	3.50
Trips / User / Month	12.27	12.83	9.83

* Commute Equivalent Trips. Category 1 = 0 trips, Category 2 = 3 trips, etc.

The goal is to calculate total cost to MIT. This requires the actual number of transit trips and days parked at MIT. As shown in the table below, adding up the weighted days parked in the month of October (non-binned) amounts to 6% less than the commute equivalent trip calculation. To measure the use of the parking facilities requires multiplying CEQT by its ratio to the number of days parked. For transit one-way linked trips, based on the earlier finding that 41% of transit usage is non-commute, it is not surprising that the ratio is much higher – at approximately 2.75:1. This, of course, also accounts for the conversion of a commute roundtrip to a transit one-way trip. The results for each policy option in Chapter 7 report both the commute equivalent trips, and the actual usage of the facilities, using the above ratios to scale the CEQT.

Table A-20. Equivalent Commute Trips Vs. Actual Trips By Mode

Equivalent Commute Trips	Days Parked	Ratio
49,198	46,069	0.936

Equivalent Commute Trips	Transit Linked (one-way) trips	Ratio
71,621	197,053	2.751

MODELING EXPECTATIONS

The decision to include or exclude variables from the model uses the analysis in Chapter 6 as a departure point. The policy options to be analyzed change the current transportation subsidy regime. Thus, the goal is to understand the effect of the daily and monthly cost of parking and transit on total usage of MIT parking facilities and trips by transit. Including demographic and socioeconomic variables and proxy variables increases model accuracy. The following are the explanation of the variables in the model, and expectations for significance and directionality.

1. Monthly Cost. This variable is created by the attributes of each of the monthly permit and pass types. For example, monthly parking permits are $65.50 and Carpool permits cost $16.38 per month, whereas Zone 8 Commuter Rail passes

are $125, and Occasional Parking Permits in combination with a LinkPass are $4 + $29.50 = $33.50. The goals of the model and the method of modeling monthly cost are intertwined. Recall that there are 3 goals for the model: (1) to understand and describe commute choice (therefore it is appropriate to keep the fixed monthly costs of transit and parking separate); (2) to provide meaningful forecasts for policy options (either choice may be appropriate); and (3) to fit into the behavioral inferences about how people consider the cost of each policy option (the policy options considered blur the costs attributed to parking and those attributed to transit that have heretofore been kept separate). If these costs enter the model separately and are found to have different effects in sign or magnitude, there is then a problem in attributing the costs in the policy options. Modeling them in both fashions (separate and combined) tests these hypotheses. Finding that there is not a significant difference between these models allows the costs to be combined, and all three of the goals to be met. If there is a significant difference, a decision of whether to use the model that better describes behavior, or the one that creates better behavioral inferences for policy is necessary. Assuming that there is little difference between the models, and that fixed costs for parking and transit are combined, the expectation is that this will be negative; that is that no cost is preferred to a program that is costly.

2. Daily Driving Cost. This variable is created by combining the daily cost of parking—based on the attributes of the type of permit (or lack thereof) held by the employee—with the cost of driving to MIT. Each person who took the survey has been geographically identified based on his or her address kept on file by MIT. A skim of the existing road network finds the shortest path to MIT. This results in a measure of total miles travelled on the commute for each individual, which in turn feeds the variable cost of the drive trip. Assuming that each car gets 25 mile to the gallon, and that the cost of gas is $2 per gallon; the cost of gas is $0.08 per mile. For parking costs, the cost for those people with a monthly permit is $0 on a daily basis, for Occasional Permit holders it is $4, and for those people without permits it is the going daily rate at adjacent private lots of $12. This is a simplification that ignores the availability of metered and unmetered on-street parking adjacent to campus. Combining these costs is equivalent to the twin assumptions that people (1) do not consider the depreciation and other costs of car maintenance in their daily decision and (2) consider the cost of the journey as a whole, rather than as independent pieces. The expectation is that this will be negative, and that the more people drive, the more negative it will be – that is their increased use is in essence an increase in cost. This is similar to (Ben-Akiva & Bowman, 1998), who find in their preliminary results that low income does not increase cost sensitivity for the primary work tour, but that free parking reduces or removes the disutility of driving alone.

3. Daily Transit Cost. For those people with monthly passes, this cost is $0. For those people without monthly passes, the model assumes the cash fare cost of a linked one-way trip is $2 (rather than the CharlieCard cost of $1.70 – this effects

the relative weights of the Betas, but not the overall results). This is a simplification. In fact, this cost will be variable depending on where they live, and how they purchase the pass. For example, if they live in an area where they would take Commuter Rail, their daily price would be higher, but they could reduce it by purchasing a ten-ticket pack. Without the actual routes that people use to commute, inferring transit fares would require a set of assumptions that would not be able to be validated. Therefore, the daily cost is not varied in the model based on location. The expectation is that the effect will be similar to that of the daily cost for driving – negative and increasing in effect with the number of trips.

4. Travel Time. The time it takes to drive is not derived from a model, but from the responses of the employee's nearest neighbors (including the employee him or herself for the mode they indicated as primary). Each survey respondent indicated their primary mode, and the amount of time their commute took to and from MIT on an average day. The responses of all of the employees in the same Traffic Analysis Zone (TAZ) as the respondent are averaged by mode. If there are fewer than 5 respondents in the TAZ, this measure includes the responses of those people within ½ mile of the TAZ, in order to get a less variable estimate of the commute time. Those TAZ's that do not have any respondents either within the zone or nearby for a mode are assumed to not be viable for travel to MIT. There are no respondents who do not have the drive mode available to them, fewer than 2% who do not have transit, and 20% who do not have walking or biking available. The availability derived from this measure feeds which alternatives are evaluated by the model. In this way, it prevents those people who do not have a viable non-motorized option available to them from switching to it, both in the initial estimation process and in the simulation of policy alternatives.
    a. Drive Time. The expectation is that this will negative, and that it will be less negative the more this travel is part of habit – that is the more often someone partakes in it. The longer the trip is the less negative the marginal time it takes will be.
    b. Transit Time. The expectation is that this will be negative. While it may see similar changes based on frequency as drive time, exclusive transit use (transit captive), may be less of choice than driving often, and thus may not particularly vary with the frequency of use.
    c. Bicycle / Walk Time. The expectation is that this will be negative. While it may again be similar to the effects of drive and transit as frequency increases, it may also increase with frequency of use. The inference behind this hypothesis is that for those people that rarely travel by this method it is recreational (and thus the travel time is pleasurable, or at least less negative), while those people who do it everyday are more likely to view it as part of their routine, which may not be choice, and thus are sensitive to the time it takes.

5. Gender. Chapter 6 showed that women are less likely to engage in pedestrian behavior. The expectation is therefore that there will be a negative effect on those choices that include non-transit or drive trips for a female dummy variable.

6. Car Ownership and Licensed Drivers. Those people without cars or without drivers' licenses will be more likely to have no drive trips (although it is still possible that they have a drive trip, in a ridesharing situation). The expectation is that there is a similar inclination toward no drive trips for those people who have one car or one driver's license in their household, but of a smaller magnitude than those people without cars or licenses.

7. Move Year. Chapter 6 demonstrated that this a proxy variable for how settled the person is in their location and in their lifecycle, although it is confounded by an interaction with age. The expectation is therefore that people who have moved in the last few years will be more likely to have more transit and more pedestrian/other trips.

8. Job Type. Chapter 6 also demonstrated that this was to some degree a proxy for both income and the lifecycle stage of the person. There were different patterns for Faculty, Administrative Staff, and Medical Staff than for other employees. The expectation is therefore that these groups will be more likely to drive more often. A further expectation is that Medical Staff, because they are often on call, will be more likely to use very little transit. Additionally, Other Academic Staff will be less likely to drive. If job type is in fact a proxy for income, the expectation is a replication of (Bhat, 2001)'s findings that that higher income increases the propensity to make shopping trips, which is hypothesized to increase the propensity to use drive as a mode.

9. Age. Chapter 6 showed that those people who were older were more likely to drive and less likely to walk or bike to MIT. Transit usage declined with age. The expectation is therefore that there is less non-commute use of transit as people age. This is similar to (Bhat, 2001), who found in her analysis of the 1991 Boston household Activity Survey that age has a positive effect on the choice of public transit for non-commute trips, but decreases in magnitude with age.

10. Transit Accessibility. Based on the exploration of proxies for transit accessibility in Chapter 6, both by distance to types of transit, and by those people within a set distance of the employee who indicated that they used transit the expectation is that the distance to nearest neighbor with transit this will have a positive effect on transit usage for those people who also drive.

11. Changed Modes Recently or Considering Change. This is a proxy for those people who currently drive, but are unsettled in their mode, and for those people who recently switched modes, and therefore are still considering their options. That is, it is negatively correlated with the existence of a mode choice habit. The

expectation is therefore that those people who recently changed modes will be less likely to be mode exclusive. Those people who are considering change will be less sensitive to the daily cost, because they view their current mode as temporary.

12. Bicycle Ownership. Not having a bicycle will decrease the likelihood of having a non-motorized commute. In the reverse, the expectation is that ownership this will have a positive effect on the propensity to have a non-motorized commute.

13. Use Vehicle For MIT Business. This will make people less sensitive to the daily cost of driving, especially to the daily cost of driving everyday, because they perceive that there is less choice. There is also the expectation that this will decrease the propensity to drive everyday, not because they choose not to drive, but because they are less likely to park at MIT if they are using the vehicle for Institute business.

14. Arrival Time. There is more on-street parking available at earlier hours, and less congestion on the auto network. The expectation is therefore that this measure (arriving before 7am) will increase the propensity to have no transit trips.

15. Departure Time. People who leave late (after 8pm) are less likely to have children and/or a family that require household duties or other obligations. This is associated with a transit and pedestrian-oriented, urban lifestyle. While there may be less frequent MBTA service at this hour, the expectation is that the lifecycle effect outweighs the service availability effect. The expectation is therefore for an increased propensity to not drive to MIT at all.

16. Travel Back by Different Mode. This is another proxy for having a more flexible lifestyle and therefore also a more flexible commute. The expectation is therefore that they will be more likely to have transit trips (or, in the reverse, less likely to have reported no transit trips in the month).

17. Park, but not at MIT. There are a number of people who reported that they drove to MIT, but parked either in a private lot, or on the street. The expectation is therefore that they will not have parked in a MIT lot, regardless of the amount of transit they report using.

The choice of zero trips by either mode implies that there is little flexibility in the person's commute. The expectation is therefore that all combinations of drive and transit trips will be preferred to a situation where there are not trips by transit or driving (that is, that holding the choice with zero trips by either mode at 0, all alternative specific constants will be positive). People without recorded trips are not able to make any trips during the day because they do not have a car available to them and choose not to use transit. Or, they park at someplace other than MIT, and thus either are feeding a meter during the day, are concerned about finding a parking spot, or are paying a higher price for parking than they otherwise would. If they are dropped off at MIT, they are dependent on someone to pick them up at the end of the day. Even if they walk everyday, their lack of transit trips implies that their non-commute choice set is constrained.

MODEL FINDINGS

Based on those expectations, the discrete choice of trips by transit and days parked was estimated using the BIOGEME software program (Bierlaire, BIOGEME: A free package for the estimation of discrete choice models, 2003) and the DONLP2 algorithm, a sequential equality constrained quadratic programming method (Bierlaire, 2008). The modeling process began with alternative specific constants for each choice. Each variable was added in a systematic, structured and incremental fashion, testing out different formulations and interactions for each variable, in order to maximize the explanatory power of the model. Variables were rejected from use if they did not add to the explanatory power of the model (using a likelihood ratio test). All variables that were included have the expected directional effect, however not all of the expectations outlined above were met. A number of variables that do not meet the 95% test for robust significance were kept in the model because *a priori* they effect the mode choice decision, and had the expected magnitude and direction. (Ben-Akiva & Lerman, 1985)

Table A-21. Choice Option Key

	Transit CEQT				
Parking CEQT	**0**	**1 -5**	**6-10**	**11-15**	**16-20**
0	1	6	11	16	21
1-5	2	7	12	17	22
6-10	3	8	13	18	23
11-15	4	9	14	19	24
16-20	5	10	15	20	25
Total	30.7%	16.8%	10.9%	7.4%	34.3%

Table A-22. Model Specification

Key: x. use beta in alternative without suffix
00, 05, 10, 15, 20. Use beta in alternative with commensurate suffix

Key	ASC	1	2	3	4a	4a	4b	4c	5	6a	6b	7a	7b
Alternative	**Alternative Specific Constant**	**Fixed Cost**	**Daily Cost (Drive)**	**Variable Cost (Transit)**	**Log Travel Time (Drive) * Nearest Transit Neighbor > 1/10 mile**	**Log Travel Time (Drive) * Nearest Transit Neighbor > 1/10 mile * Commute Over 45 minutes**	**Log Travel Time (Transit)**	**Log Travel Time (Ped)**	**Female**	**No Car**	**One Car**	**Moved Before 2006**	**Moved After 2006**
BETA	ASC_	B_COST_FIXED	B_COST_D_D	B_COST_T_T	B_TIME_D	B_TIME_DSQ	B_TIME_T	B_TIME_P	B_FEMALE	B_NOCAR	B_ONECAR	B_MOVE_D	B_MOVE_T
1	T00D00							20	x	x	x	x	
2	T00D05	x	05		05			15	x			x	
3	T00D10	x	10		10	x		10	x			x	
4	T00D15	x	15		15	x		05	x			x	
5	T00D20	x	20		20	x							
6	T05D00	x		05			05	15	x	x	x	x	05
7	T05D05	x	05	05	05		05	10	x			x	05
8	T05D10	x	10	05	10	x	05	05	x			x	05
9	T05D15	x	15	05	15	x	05					x	05
10	T05D20	x	20	05	20	x	05						
11	T10D00	x		10			10	10	x	x	x	x	10
12	T10D05	x	05	10	05		10	05	x			x	10
13	T10D10	x	10	10	10	x	10					x	10
14	T10D15	x	15	10	15	x	10					x	10
15	T10D20	x	20	10	20	x	10						
16	T15D00	x		15			15	05	x	x	x	x	15
17	T15D05	x	05	15	05		15					x	15
18	T15D10	x	10	15	10	x	15					x	15
19	T15D15	x	15	15	15	x	15					x	15
20	T15D20	x	20	15	20	x	15						
21	T20D00	x		20			20			x	x	x	20
22	T20D05	x	05	20	05		20					x	20
23	T20D10	x	10	20	10	x	20					x	20
24	T20D15	x	15	20	15	x	20					x	20
25	T20D20	x	20	20	20	x	20						

Key	9a	9b	10	11a	11b	11c	12	13a	13b	14	15	16	17
Alternative	Age (Interaction with Drive)	Age (Interaction with Transit)	Nearest Transit Neighbor w/in 1/10m	Change Primary Commute Mode in prior 2 years	Considering Primary Commute Mode Change	Variable Cost (Drive) * Considering Mode Change	Bike Ownership	Use Car for MIT Business	Variable Cost (Drive) * Use Car for MIT Business	Arrive at MIT before 7am	Leave MIT after 7pm	Travelled Back by Dif't Route	Parks at a non-MIT location
BETA	B_AGE_D	B_AGE_T	B_NN_TENTH	B_CHANGED	B_CHANGESOON	B_COST_D_CHANGE SOON_D	B_BIKEOWN	B_MITBUSINESS	B_COST_D_MIT_D	B_EARLY	B_LATE	B_TRAVBACK_D	B_NONMITPARK
1	00			x	x		x			x	x	x	x
2	05			x	x		x		05	x		x	
3				x	x	10			10	x		x	
4				x	x	15			15	x		x	
5				x	x	20		x	20	x		x	
6	00		x				x				x		x
7	05		x				x		05				
8			x			10			10				
9			x			15			15				
10			x			20		x	20				
11	00		x								x		x
12	05		x						05				
13			x			10			10				
14			x			15			15				
15			x			20		x	20				
16	00	15	x				x				x		x
17	05	15	x				x		05				
18		15	x			10			10				
19		15	x			15			15				
20		15	x			20			20				
21	00	20	x	x	x						x		x
22	05	20	x						05				
23		20	x			10			10				
24		20	x			15			15				
25		20	x			20			20				

Table A-23. Model Results

Key	Name	Value	Robust Std err	Robust t-test	p-value	
Alt 1	ASC_T00D00	0				
Alt 2	ASC_T00D05	4.88	1.16	4.19	0	
Alt 3	ASC_T00D10	4.44	1.24	3.58	0	
Alt 4	ASC_T00D15	3.3	1.31	2.51	0.01	
Alt 5	ASC_T00D20	1.87	1.26	1.49	0.14	*
Alt 6	ASC_T05D00	4.47	1.27	3.51	0	
Alt 7	ASC_T05D05	6.75	1.49	4.52	0	
Alt 8	ASC_T05D10	5.97	1.57	3.79	0	
Alt 9	ASC_T05D15	3.74	1.53	2.44	0.01	
Alt 10	ASC_T05D20	5.57	1.52	3.66	0	
Alt 11	ASC_T10D00	5.66	1.33	4.24	0	
Alt 12	ASC_T10D05	8.29	1.6	5.19	0	
Alt 13	ASC_T10D10	5.97	1.61	3.71	0	
Alt 14	ASC_T10D15	4.93	1.69	2.91	0	
Alt 15	ASC_T10D20	7.72	1.62	4.76	0	
Alt 16	ASC_T15D00	4.12	1.35	3.04	0	
Alt 17	ASC_T15D05	4.66	1.65	2.83	0	
Alt 18	ASC_T15D10	5.81	1.66	3.51	0	
Alt 19	ASC_T15D15	5.39	1.72	3.13	0	
Alt 20	ASC_T15D20	6.48	1.74	3.73	0	
Alt 21	ASC_T20D00	2.83	1.19	2.37	0.02	
Alt 22	ASC_T20D05	6.03	1.3	4.63	0	
Alt 23	ASC_T20D10	6.4	1.33	4.83	0	
Alt 24	ASC_T20D15	5.58	1.42	3.93	0	
Alt 25	ASC_T20D20	5.69	1.47	3.86	0	
1	B_COST_FIXED	-0.0424	0.00625	-6.79	0	
2	B_COST_D_D05	-0.561	0.0312	-18.01	0	
2	B_COST_D_D10	-0.836	0.0684	-12.23	0	
2	B_COST_D_D15	-1.12	0.129	-8.66	0	
2	B_COST_D_D20	-1.52	0.104	-14.66	0	
3	B_COST_T_T05	-0.748	0.117	-6.36	0	
3	B_COST_T_T10	-1.21	0.115	-10.5	0	
3	B_COST_T_T15	-1.72	0.125	-13.77	0	
3	B_COST_T_T20	-1.98	0.11	-18.1	0	
4a	B_TIME_D05	-0.14	0.109	-1.29	0.2	*
4a	B_TIME_D10	-0.241	0.118	-2.05	0.04	
4a	B_TIME_D15	-0.0774	0.114	-0.68	0.5	*
4a	B_TIME_D20	-0.0578	0.111	-0.52	0.6	*
4a	B_TIME_DSQ	0.419	0.193	2.17	0.03	
4b	B_TIME_T05	-0.908	0.304	-2.99	0	
4b	B_TIME_T10	-1.58	0.363	-4.35	0	
4b	B_TIME_T15	-1.37	0.418	-3.27	0	
4b	B_TIME_T20	-1.3	0.391	-3.34	0	
4c	B_TIME_P05	-0.912	0.264	-3.46	0	
4c	B_TIME_P10	-1.4	0.28	-4.99	0	

Key	Name	Value	Robust Std err	Robust t-test	p-value	
4c	B_TIME_P15	-1.96	0.306	-6.4	0	
4c	B_TIME_P20	-2.01	0.355	-5.68	0	
5	B_FEMALE	-0.36	0.0981	-3.67	0	
6a	B_NOCAR	2.55	0.587	4.34	0	
6b	B_ONECAR	0.784	0.179	4.38	0	
7a	B_MOVE_D	0.498	0.257	1.94	0.05	*
7b	B_MOVE_T05	0.176	0.139	1.27	0.21	*
7b	B_MOVE_T10	0.508	0.151	3.36	0	
7b	B_MOVE_T15	-0.0939	0.308	-0.3	0.76	*
7b	B_MOVE_T20	0.602	0.14	4.31	0	
9a	B_AGE_D00	0.0284	0.00949	2.99	0	
9a	B_AGE_D05	0.0186	0.00795	2.35	0.02	
9b	B_AGE_T15	-0.0101	0.00726	-1.4	0.16	*
9b	B_AGE_T20	-0.0201	0.00609	-3.3	0	
10	B_NN_TENTH	0.298	0.175	1.71	0.09	*
11a	B_CHANGED	-0.495	0.107	-4.62	0	
11b	B_CHANGESOON	-0.347	0.117	-2.97	0	
11c	B_COST_D_CHANGESOON_D10	0.153	0.0519	2.94	0	
11c	B_COST_D_CHANGESOON_D15	0.293	0.091	3.22	0	
11c	B_COST_D_CHANGESOON_D20	0.267	0.105	2.54	0.01	
12	B_BIKEOWN	0.345	0.103	3.35	0	
13a	B_MITBUSINESS	-0.678	0.237	-2.87	0	
13b	B_COST_D_MIT_D05	0.185	0.0299	6.17	0	
13b	B_COST_D_MIT_D10	0.194	0.0543	3.58	0	
13b	B_COST_D_MIT_D15	0.205	0.0907	2.26	0.02	
13b	B_COST_D_MIT_D20	0.422	0.148	2.85	0	
14	B_EARLY	0.796	0.373	2.14	0.03	
15	B_LATE	0.857	0.343	2.5	0.01	
16	B_TRAVBACK_D	-0.727	0.218	-3.34	0	
17	B_NONMITPARK	2.09	0.44	4.75	0	

*. Not significant at 95%

n = 2820
Null log-likelihood = -8664.231
Init log-likelihood = -8664.232
Final log-likelihood = -4060.019
Likelihood ratio test = 9208.426
Rho-squared = .523

Overall, the model has an adjusted Rho^2 of .523. More importantly, most of the expectations for significance indicated earlier have been met. The results for each variable are compared to expectations below. In some cases, to give a sense of the magnitude of the change implied, especially for dummy variables, the value of the beta is compared to the alternative specific constants.

1. Monthly Cost (B_COST_FIXED). This is negative, as expected. A dollar here also means less than a dollar in variable cost, as expected, since there are multiple days in a month. Depending on the number of trips and the mode, a dollar of fixed cost is worth between $12 and $45 of variable cost. When the costs of driving and transit are combined, some of the descriptive power of the model is lost (Rho^2 decreases from .524 to .523, and the final log-likelihood increases from -4042.162 to -4060.019). When these fixed costs are separated, driving is about 60% as negative as transit (that is a coefficient of -0.025 vs. -0.045) for those people who drive 5 or fewer commute equivalent trips, or 16 or more commute equivalent trips, and the same levels as transit for the middle options. This may be due to the majority of the drivers falling into those edge choices, and the differential in monthly pricing commensurate with them (0-5 CEQT = Occasional Permits; 16+ CEQT = Monthly Permits). Nevertheless, it is important to note the effect of the equality constraint imposed in order to better fit this thesis' policy options. That is, there will be more sensitivity to fixed costs in the edge options than there would otherwise be without this constraint.

2. Daily Driving Cost (B_COST_D_D05, B_COST_D_D10, B_COST_D_D15, B_COST_D_D20). This is negative, as expected, and increasing in relative weight the more people drive, in more or less direct proportion to the number of drive trips. No significant interactions with income proxies were found. By constraining the daily parking cost coefficient to be equal to the coefficient for the cost of gas the significance of the model is slightly decreased, but the ability to apply the model to policy options is increased.

3. Daily Transit Cost (B_COST_T_T05, B_COST_T_T10, B_COST_T_T15, B_COST_T_T20). Similar to the variable cost of driving, this is negative and proportional to the amount people take transit, as expected.

4. Travel Time. Each of these measures refers to the natural log of time by mode. This was done to remove the highs and lows, and because it better fit the data.
    a. Drive Time (B_TIME_D05, B_TIME_D10, B_TIME_D15, B_TIME_D20, B_TIME_DSQ). The expectation was that this would be negative, but would be less negative the more often people drove. It was also expected that for trips farther out it would be less negative. No relationships could be found when using straight drive time. This may be because it is highly correlated with both transit time and pedestrian time. To correct for this correlation drive time enters the model only for those people who do not have a nearby neighbor who uses transit. In this case it is slightly more significant, and has the expected values. However, it is only significant at the 95% level for people who drive 5-10 times per month. Furthermore, for trips over 45 minutes by drive, the drive time is actually positive.
    b. Transit Time (B_TIME_T05, B_TIME_t10, B_TIME_T15, B_TIME_T20). This met expectations: it is negative, significant, and relatively invariant with use, although slightly lower in magnitude for people who take 1-5 Commute Equivalent Trips.

    c. Bicycle / Walk Time (B_TIME_P05, B_TIME_P10, B_TIME_P15, B_TIME_P20). This also met expectations, in that it was highly significantly, negative, and increases with use, up to 15 trips per month.

5. Gender (B_FEMALE). There was a negative effect on pedestrian trips as expected, equivalent to approximately 10% of the Alternative Specific Constant for those trips.

6. Car Ownership and Licensed Drivers (B_NOCAR, B_ONECAR). Both those people with no cars or licenses and one car or license were significantly more likely to not have any parking events at MIT. This was equivalent to 40-50% of the alternative specific constant (depending on the number of transit trips) for people who had no cars or drivers in their household, and 10-15% for people with only one car or driver in their household.

7. Move Year (B_MOVE_D, B_MODE_T05, B_MODE_T10, B_MODE_T15, B_MODE_T20). Those people who moved between 2006 and 2008 were more likely to drive less frequently than every day, or not at all, at the equivalent of approximately 10% of the alternative specific constants. They were also more likely to take transit, but the effect and significance varied by the number of commute equivalent trips. It was significant and in the expected direction for people with 10 or 20 CEQT, and insignificant but in the expected direction for people with 5 equivalent trips. For those people with 10 CEQT it had almost no effect, and was not significant. This might mean that travel for those people who recently moved was more likely to be dominant toward one mode or the other. This is in keeping with the hypothesis that the type of subsidies that are currently offered encourage this behavior, especially for people who are closer to equilibrium. That is, it is a coping strategy to commute more by a single dominant mode.

8. Job Type. Significant effects could not be found for any job type, whether Faculty, Administrative Staff, Medical staff, or Other Academic Staff either by themselves, or as a modifier of the perceived cost of driving or transit. The difference between these groups is a result of age and lifecycle, not one of income or inherent preference. What appears to be a trend if looking only at these groups is the result of the distribution of people of different ages between these groups.

9. Age (B_AGE_D00, B_AGE,D05, B_AGE_T15, B_AGE_T20). Numerous ways of adding age to the model were attempted, including using multiple variations of a piecewise linear function. Only two relatively minor effects were found to be significant; both of them are linear with age. People are more likely to drive 0 or 5 times as the increase in age. They are also less likely to take 15 or 20 commute equivalent trips by transit, although only the second of those is significant at 95%. In combination, this may indicate that older people, all else constant, are more likely to rideshare, or otherwise not use MIT facilities for their commute

purposes. For example, the proportion of faculty who are older is relatively high, and many of them have more flexible schedules that do not require them to be on campus as often. While this exact phenomenon might not have caused this result, it is one possible explanation.

10. Transit Accessibility (B_NN_TENTH). As expected, for those people who drive and live within 1/10 of a mile of someone else, there is a positive effect on the likelihood to use transit at all. However, this effect is relatively small, and is only significant at the 90% level. None of the other accessibility measures had a significant effect on the explanatory power of the model.

11. Changed Modes Recently or Considering Change (B_CHANGED, B_CHANGESOON, B_COST_D_CHANGESOON_D10, B_COST_D_CHANGESOON_D15, B_COST_D_CHANGESOON_D20). The hypothesis was that this is a proxy for people who drive, but are not happy about it. People who changed recently, or are considering change, are less likely to be mode exclusive, by 10-20% of the alternative specific constant. Employees who are considering moving are approximately 20% less sensitive to the cost of driving for more than 6 trips to MIT. This may be because they are more likely to demonstrate flexibility in their mode choice, and are less mediated by habit.

12. Bicycle Ownership (B_BIKEOWN). As expected, this increases the tendency to have chosen an option that has fewer than 20 combined transit and drive commute equivalent trips. However, the effect is relatively small, at only 10% of the average alternative specific constant.

13. Use Vehicle For MIT Business (B_MITBUSINESS, B_COST_D_MIT_D05, B_COST_D_MIT_D10, B_COST_D_MIT_D15, B_COST_D_MIT_D20). As expected this made people 20-30% less sensitive to driving, especially for those times when people travel by car every day. It also made people less likely to have 20 drive trips to MIT by car, as expected.

14. Arrival Time (B_EARLY). This had an effect of increasing the propensity of people to have no transit trips, equivalent to approximately 20% of the alternative specific constant for those people arriving before 7am.

15. Departure Time (B_LATE). As a proxy for lifecycle, this increased the propensity to have zero drive trips to MIT, by 20% of the alternative specific constant. These people are more likely to be reliant on transit.

16. Travel Back by Different Mode (B_TRAVBACK_D). As another proxy for lifecycle, the findings are as expected: this decreases the propensity to have no transit trips in their monthly trip bundle.

17. Park, but not at MIT (B_NONMITPARK). As expected, this increases the propensity to have recorded 0 drive trip. The effect is quite large: 40-70% of the alternative specific constants.

Lastly, comparing the alternative specific constants (ASC_T00D00, ASC_T00D05 … ASC_T00D20, ASC_T05D00 … ASC_T20D20), allows an examination of the *ceteris parabus* (all else being equal) preferences. All options are preferred to the option of no recorded travel. The most popular are splits where there is a mixture of transit and driving. The highest value is for 1-5 equivalent drive trips, and 6-10 equivalent transit trips, followed by 6-10 transit trips and 16-20 drive trips. The least popular are those modes that are exclusive – the lowest value is for 16-20 drive trips and no transit trips, followed by 16-20 transit trips and no drive trips. That a significant portion of the sample are in these groups indicates the degree to which people's locations, activity patterns, etc. make them captive to mode choices that, all else being equal, they would not prefer. There is strong evidence that patterns that allow flexibility of commute and non-commute trips by trip purpose are much preferred to those choices that imply little flexibility. This is yet more evidence that the single mode man is more the result of the structure of benefits packages than an innate preference.

CONCLUSIONS

This model shows that the expectations based on demographic explorations in Chapter 6 are supported by evidence in transit trips as well as weekly mode choice patterns. Similarly, the patterns for parking events in a month at MIT are similar to the inferences found for single occupancy vehicle mode choice in a week's sample. Significantly, no effects of behavior based on job type were found. Surprisingly, after controlling for the other variables, neither were the effects of age particularly significant. The implication is that the lifecycle hypothesis of Chapter 6 manifests itself in the choices of locations and jobs – age is proxy for lifecycle, but there people across the age spectrum that have made different choices about where to locate, and how much of their mode diet to allocate to auto, transit, etc. As this model is designed to be applied to policy, this is an encouraging result. It implies that the changes the model predicts can appear across the spectrum of employees.

APPENDIX 8: COST DERIVATIONS BY MODE

Appendix 7 derived total one-way linked-trips by person based on survey responses. To derive costs from this measure requires attribution of trips to modes; fares vary by mode. Inherent is this calculation is the assumption that for all travel the user receives the best fare available. For bus travel this is $1.25 per trip; for subway and bus/subway travel this is $1.70; the commuter rail fare is assumed to be the average fare based on the distribution of passes sold at MIT, $5.75 per trip.

The starting point of trips by mode is total linked trips using the Start Min algorithm derived in Appendix 7 for all non-Commuter Rail routes. Applying the absolute minimum algorithm for each week over all subway/light rail and bus modes separately results in a minimum number of trips on each mode. Finding an estimate of the number of trips that are via bus (only) requires subtracting the minimum trips for subway from the minimum number of trips for buses, for each individual, with a minimum of zero. This is equivalent to assuming that if a person takes more trips on a single bus route than they do on a single subway route, the difference between the two is the number of trips they take just on a bus. This may underestimate the number of trips that are bus only, but it will not overestimate it. Because transfers are free, there is no need to differentiate subway only and mixed mode trips. Therefore the remainder of trips are on the Bus/Subway mode. To arrive at a final bus/subway trip count requires subtracting commuter rail trips (the sum of trips to North and South stations). The result is the total number of trips by each of the three chargeable modes for each person who answered the question regarding daily boardings.

Table A-24. Usage Of Transit By Selected Student / Employee Types By Transit Mode

	Pass / Permit	Linked Trip Value	Bus Value	CR Value	Covered Usage	Uncovered Usage
Student: Undergrad: On-Campus	None	$19	$2	$2	$0	$22
	Bus Pass	$17	$12	$4	$24	$8
	Link Pass	$47	$4	$1	$51	$1
	CR	$49	$4	$8	$61	$0
	Resident Permit	$12	$1	$1	$0	$14
	Carpool Permit	$15	$0	$0	$0	$15
	non-MIT Pass	$15	$3	$0		$18
Student: Undergrad: Off-Campus	None	$19	$3	$2	$0	$24
	Bus Pass	$25	$29	$0	$47	$7
	Link Pass	$68	$14	$1	$81	$1
	CR	$4	$0	$133	$137	$0
	Occasional Permit	$27	$0	$4	$0	$32
	Resident Permit	$15	$1	$0	$0	$16
	Carpool Permit	$7	$0	$0	$0	$7
	Commuter Permit	$0	$0	$0	$0	$0

	Pass / Permit	Linked Trip Value	Bus Value	CR Value	Covered Usage	Uncovered Usage
	non-MIT Pass	$49	$22	$0		$71
Student: Graduate: On-Campus	None	$21	$1	$2	$0	$24
	Bus Pass	$28	$10	$2	$31	$9
	Link Pass	$43	$2	$2	$45	$2
	CR	$32	$0	$0	$32	$0
	Occasional + Link Pass	$22	$0	$0	$22	$0
	Occasional + CR	$0	$0	$0	$0	$0
	Resident Permit	$14	$0	$1	$0	$16
	Carpool Permit	$7	$0	$0	$0	$7
	non-MIT Pass	$4	$0	$253		$257
Student: Graduate: Off-Campus	None	$24	$1	$2	$0	$27
	Bus Pass	$22	$15	$0	$31	$6
	Link Pass	$81	$2	$2	$83	$2
	CR	$31	$2	$133	$166	$0
	Occasional + Bus Pass	$7	$19	$0	$25	$2
	Occasional + Link Pass	$58	$2	$0	$60	$0
	Occasional + CR	$27	$2	$139	$168	$0
	Occasional Permit	$16	$2	$9	$0	$27
	Resident Permit	$23	$1	$0	$0	$24
	Carpool Permit	$6	$0	$0	$0	$6
	Commuter Permit	$11	$0	$1	$0	$12
	non-MIT Pass	$70	$5	$13		$88
Staff & Faculty	None	$32	$2	$8	$0	$42
	Bus Pass	$18	$26	$1	$39	$5
	Link Pass	$86	$3	$3	$89	$3
	CR	$15	$0	$190	$205	$0
	Occasional + Bus Pass	$9	$30	$0	$36	$2
	Occasional + Link Pass	$71	$2	$1	$73	$1
	Occasional + CR	$9	$0	$165	$174	$0
	Occasional Permit	$13	$0	$7	$0	$20
	Resident Permit	$8	$0	$0	$0	$8
	Carpool Permit	$9	$0	$2	$0	$12
	Commuter Permit	$6	$0	$1	$0	$8
	non-MIT Pass	$85	$4	$12	$0	$101

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